US009427105B2

(12) United States Patent
Hansen et al.

(10) Patent No.: US 9,427,105 B2
(45) Date of Patent: Aug. 30, 2016

(54) **BEVERAGE PREPARATION MACHINES**

(71) Applicant: **Kraft Foods R&D, Inc.**, Deerfield, IL (US)

(72) Inventors: **Nick Andrew Hansen**, Banbury (GB); **Andrew Charles Bentley**, Bloxham (GB); **Elizabeth Jane Hinckley**, Badby (GB); **Mark Richard Thomas Norton**, March (GB)

(73) Assignee: **Koninklijke Douwe Egberts B.V.**, Utrecht (NL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 203 days.

(21) Appl. No.: **14/256,734**

(22) Filed: **Apr. 18, 2014**

(65) **Prior Publication Data**

US 2014/0225285 A1 Aug. 14, 2014

Related U.S. Application Data

(62) Division of application No. 13/318,044, filed as application No. PCT/GB2010/000551 on Mar. 24, 2010.

(30) **Foreign Application Priority Data**

May 1, 2009 (GB) 0907612.6

(51) **Int. Cl.**
A47J 31/32 (2006.01)
A47J 31/44 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***A47J 31/4403*** (2013.01); ***A47J 31/0605*** (2013.01); ***A47J 31/32*** (2013.01); ***A47J 31/3695*** (2013.01); ***A47J 31/44*** (2013.01); ***A47J 31/4496*** (2013.01); ***A47J 31/46*** (2013.01)

(58) **Field of Classification Search**
CPC B01F 3/04; A47J 31/32; A47J 31/44; A47J 31/0657; A47J 31/0668
USPC .... 261/30, 64.1; 99/289 R, 295, 302 R; 426/474
See application file for complete search history.

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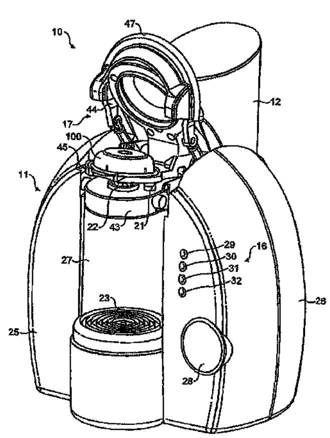
Primary Examiner — Robert A Hopkins
(74) *Attorney, Agent, or Firm* — Fitch, Even, Tabin & Flannery LLP

(57) **ABSTRACT**

A beverage preparation machine of the type which uses pre-packaged containers of beverage ingredients is described. The beverage preparation machine is configured for controlling the volume of air resident in at least a part of a delivery system of the machine to produce predetermined characteristics in a prepared beverage.

10 Claims, 21 Drawing Sheets



(51) **Int. Cl.**

A47J 31/06	(2006.01)
A47J 31/36	(2006.01)
A47J 31/46	(2006.01)

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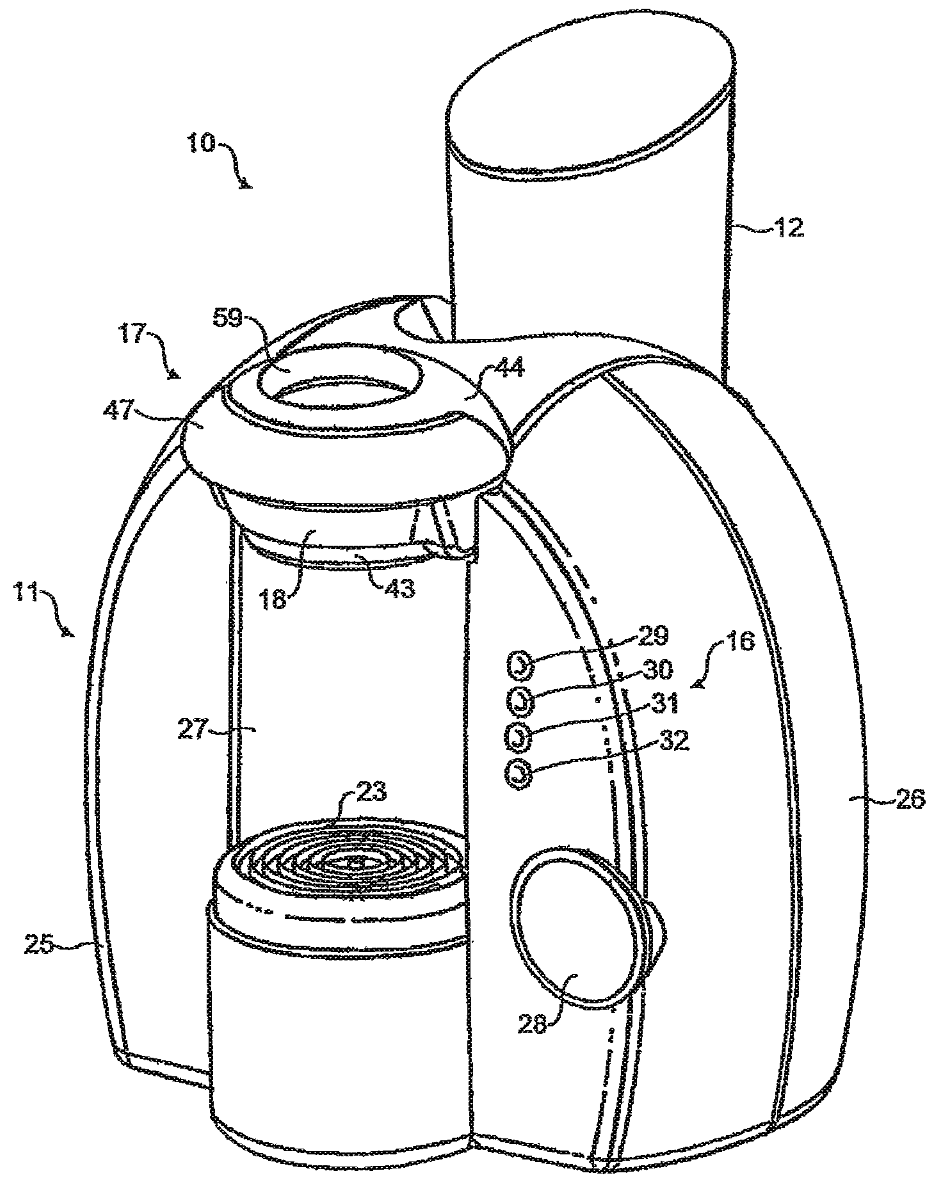

FIG. 1

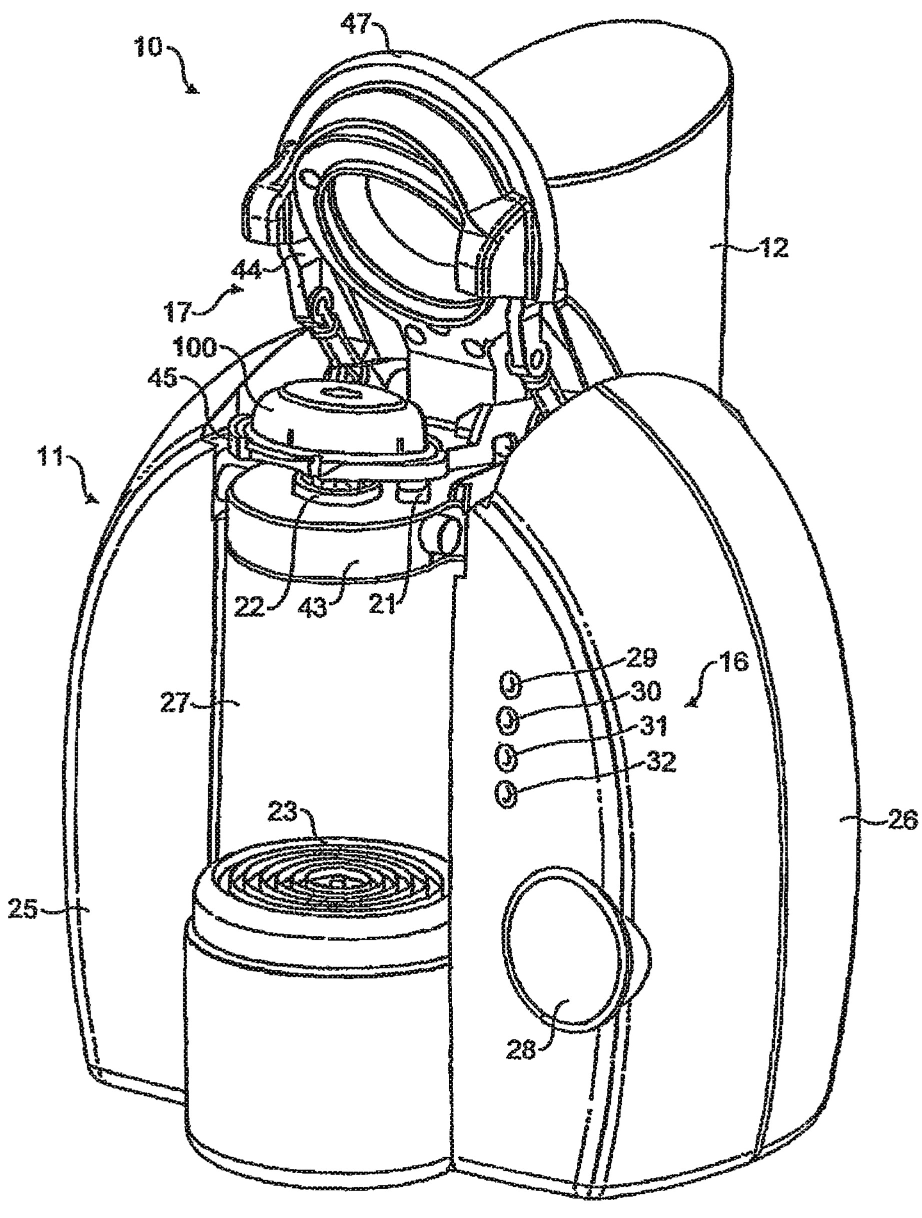

FIG. 2

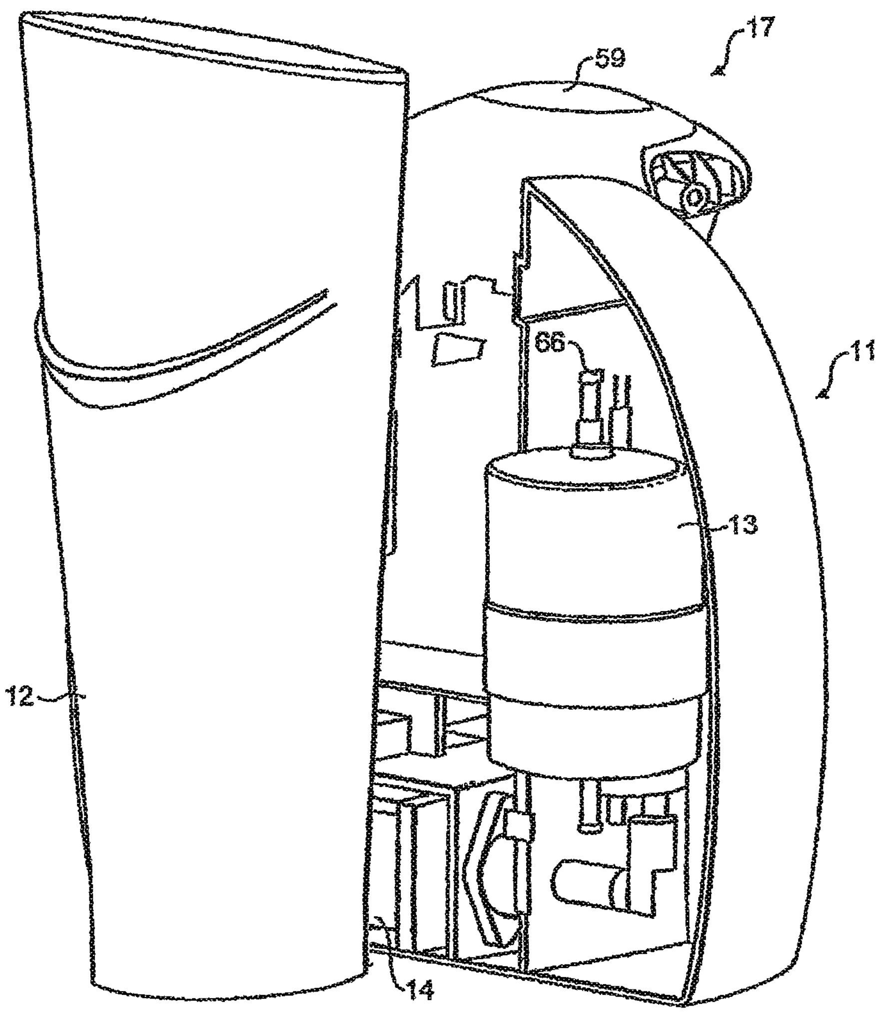

FIG. 3

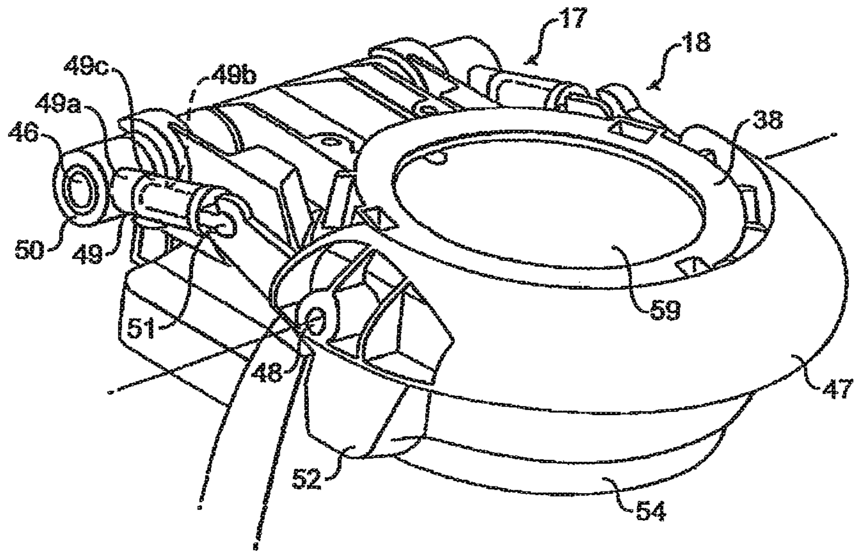
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FIG. 4

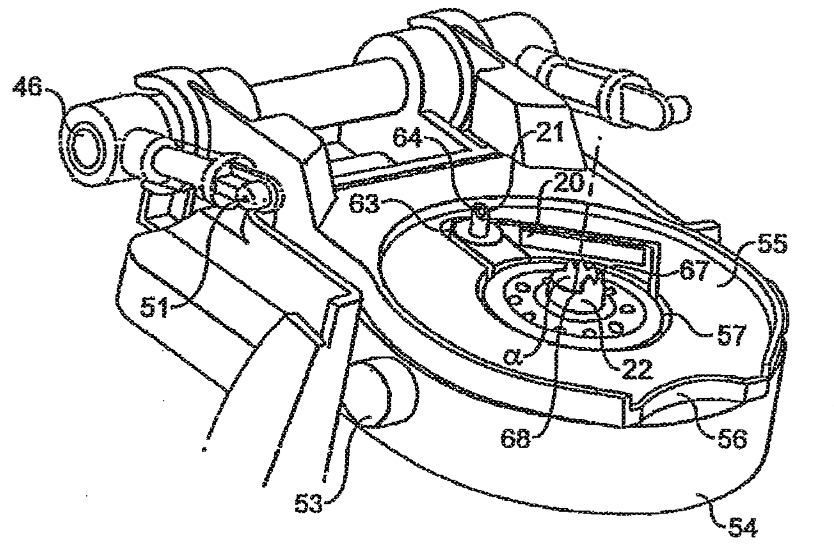
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FIG. 5

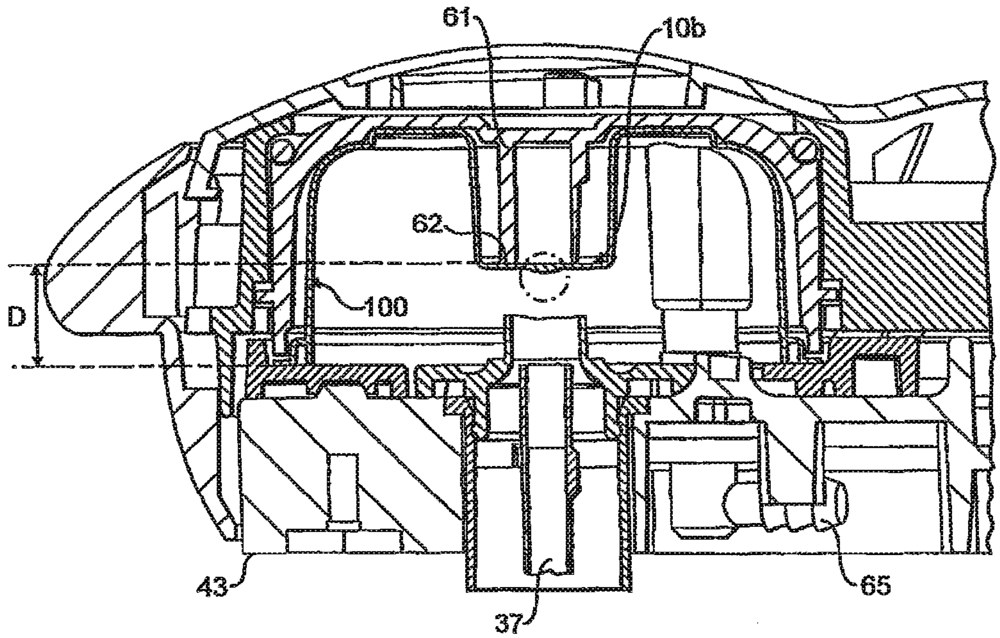


FIG. 6

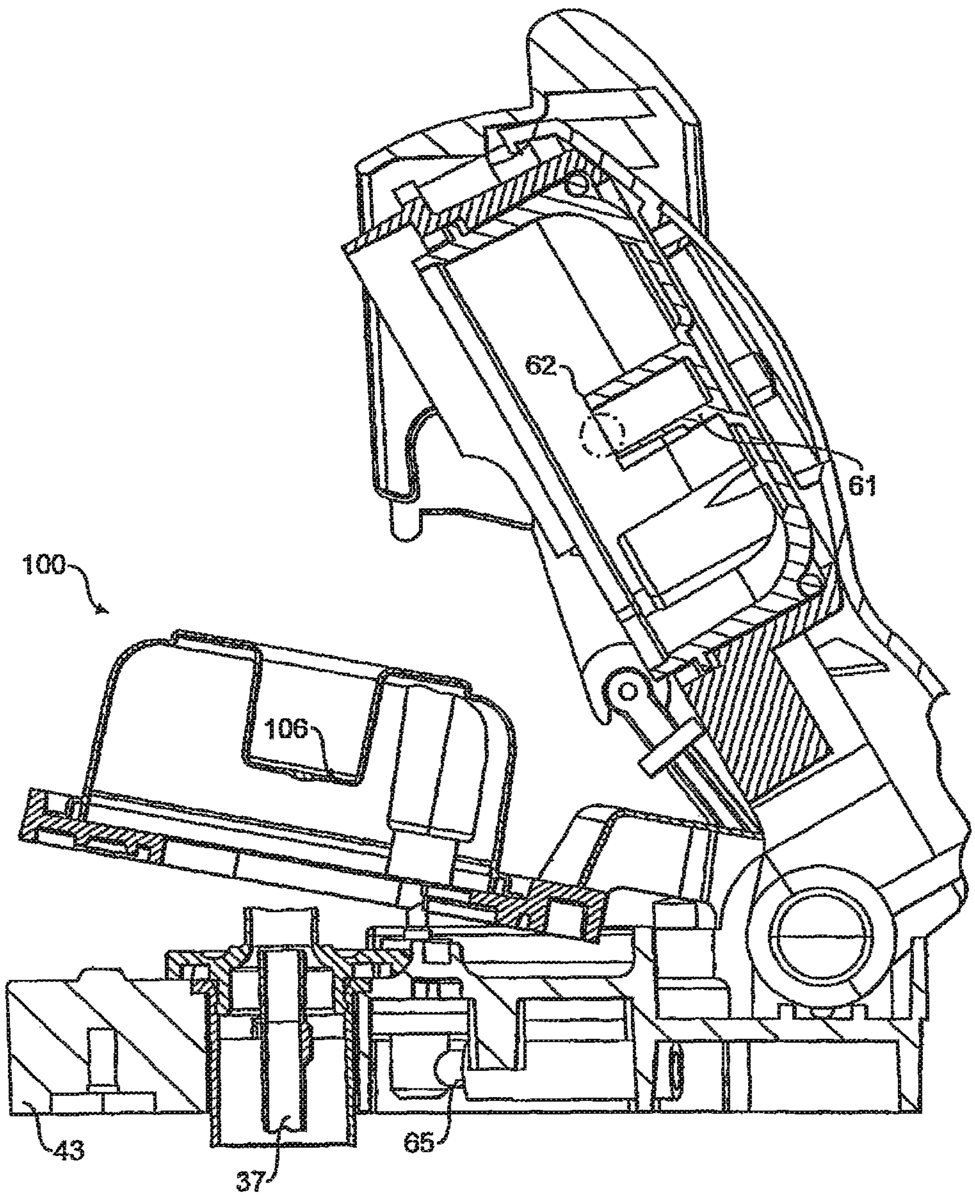


FIG. 7

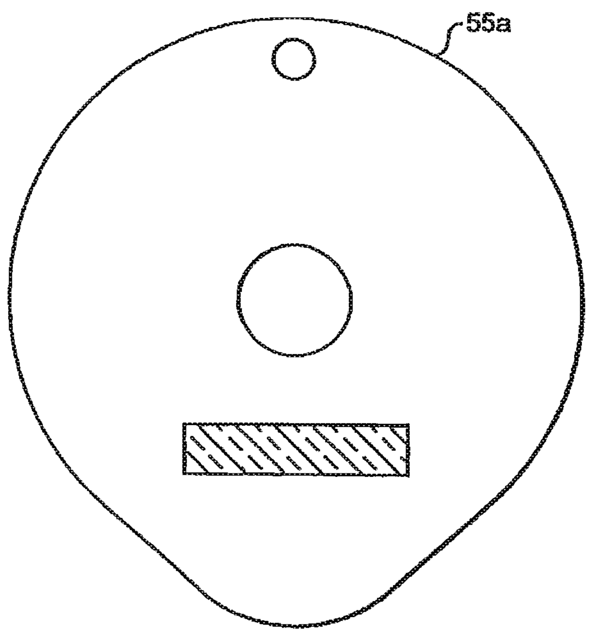


FIG. 7a

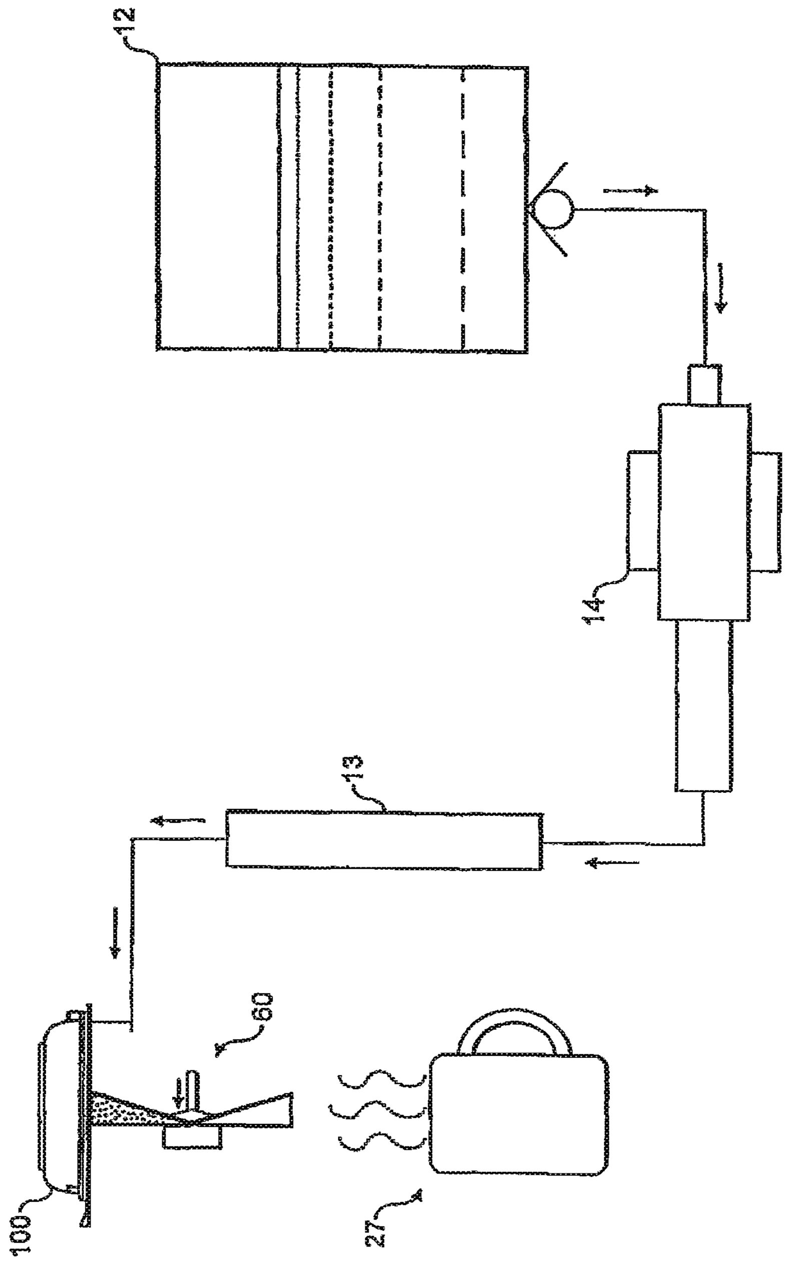


FIG. 8

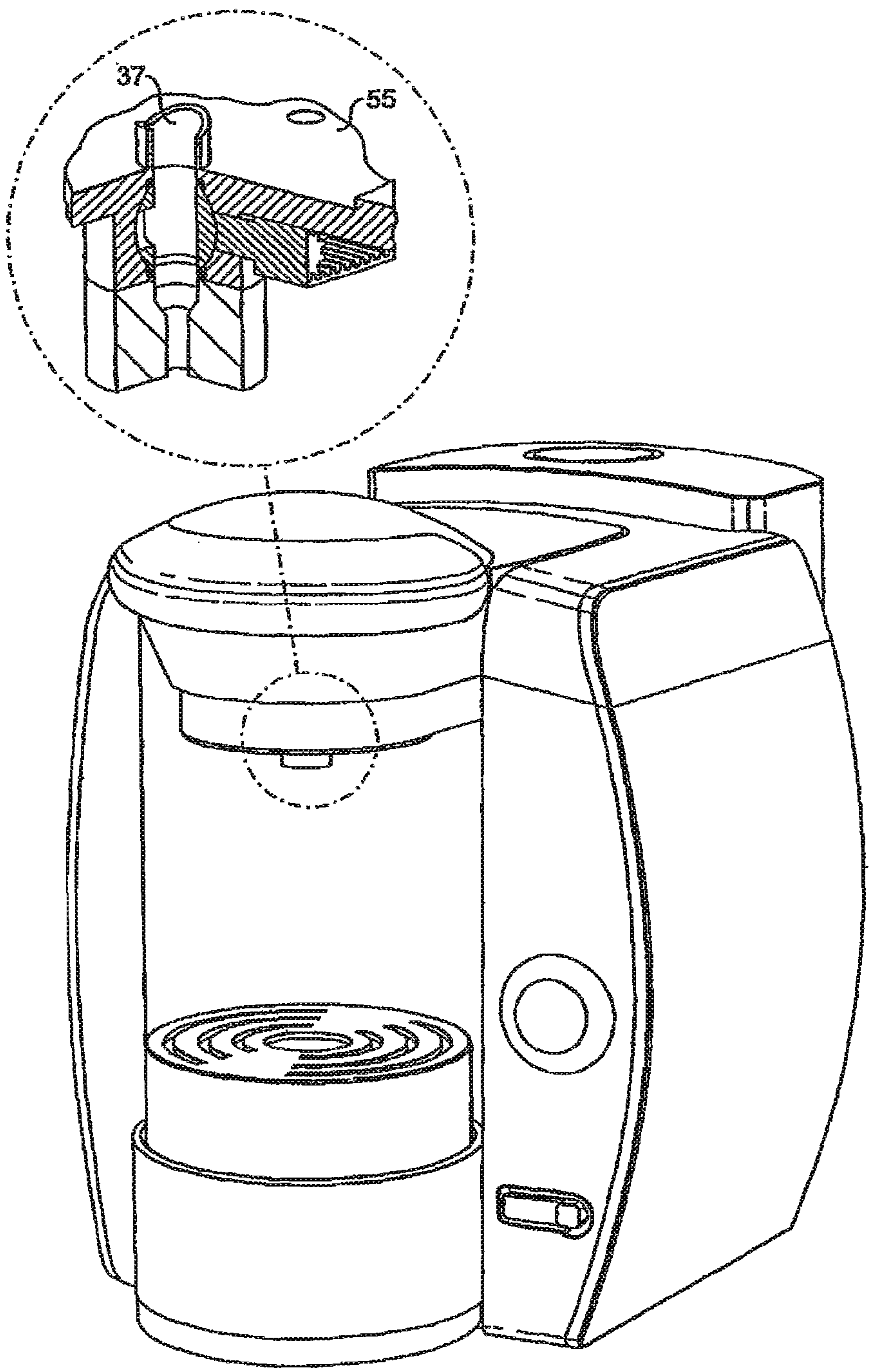


FIG 9

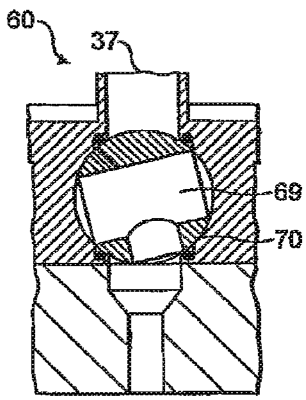
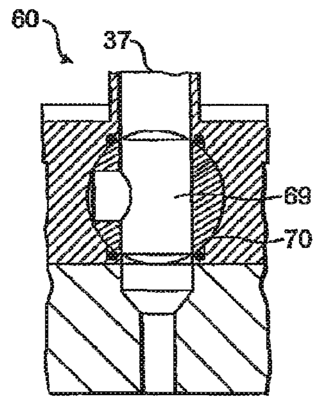


FIG. 10



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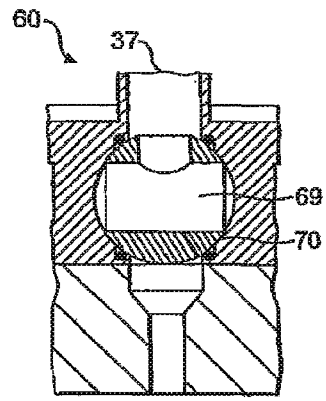


FIG. 12

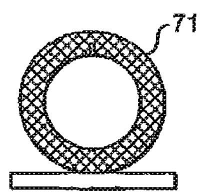


FIG. 13a

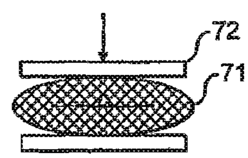


FIG. 13b

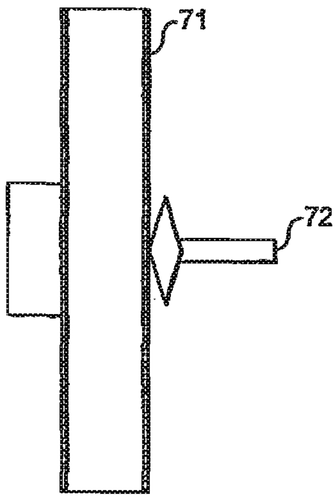
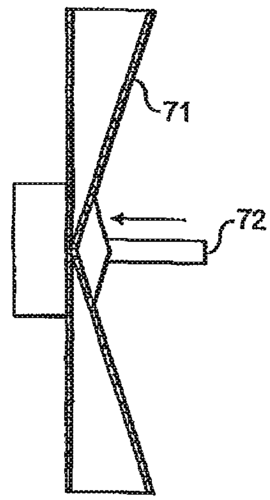


FIG. 14



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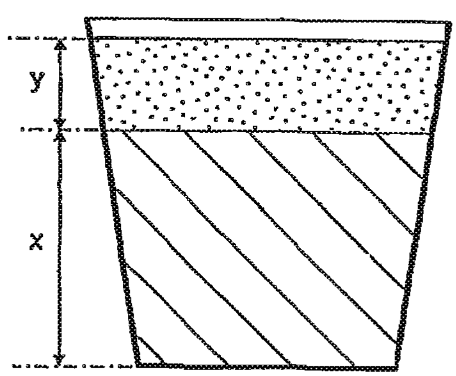

FIG. 16a

STEP	WATER PUMP STATE/SPEED	AIR PURGE PUMP/PWM	RECIRCULATION VALVE STATE	RESTRICTION BYPASS VALVE STATE	STOP CONDITION/DURATION OF STEP
Set valves	No change/0	Stop/0	Recirculate	Open	Time >=1 second
Heat	Stop/0	Stop/0	Recirculate	Open	Boiler temperature >=97°C
Set valves	No change/0	No change/0	Brew	Open	Time >=1 second
Remove gas	Run/50	No change/0	No change	Open	Time >=2 seconds
Set valves	Stop/0	No change/0	No change	Closed	Time >=5 seconds
Pressure wet	Run/100	No change/0	No change	No change	Disc inlet pressure >=2 bar
Soak	Stop/0	No change/0	No change	No change	Time >=10 seconds
Brew	Run/30	Stop/0	No change	No change	Time >=32 seconds
Stop pump	Stop/0	Stop/0	No change	No change	Time >=0.5 seconds
Open purge	Stop/0	Stop/0	No change	Open	Time >=3 seconds
Pause	No change/0	No change/0	No change	Open	Time <=1 seconds
Air purge	Stop/0	Run/50	No change	Open	Time >=8 seconds
Pause	Stop/0	Stop/0	Recirculate	No change	Time >=2 seconds
Reset	Stop/0	Stop/0	Recirculate	Closed	Time >=0 seconds

FIG. 16b

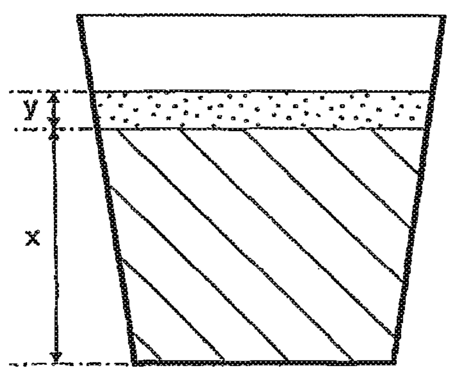

FIG. 17a

STEP	WATER PUMP STATE/SPEED	AIR PURGE PUMP/PWM	RECIRCULATION VALVE STATE	RESTRICTION BYPASS VALVE STATE	STOP CONDITION/DURATION OF STEP
Set valves	No change/0	Stop/0	Recirculate	Open	Time >=1 second
Heat	Stop/0	Stop/0	Recirculate	Open	Boiler temperature >=97°C
Set valves	No change/0	No change/0	Brew	Open	Time >=1 second
Remove gas	Run/70	No change/0	No change	Open	Time >=8 seconds
Set valves	Stop/0	No change/0	No change	Closed	Time >=5 seconds
Pressure wet	Run/100	No change/0	No change	No change	Disc inlet pressure >=2 bar
Soak	Stop/0	No change/0	No change	No change	Time >=10 seconds
Brew	Run/30	Stop/0	No change	No change	Time >=32 seconds
Stop pump	Stop/0	Stop/0	No change	No change	Time >=0.5 seconds
Open purge	Stop/0	Stop/0	No change	Open	Time >=3 seconds
Pause	No change/0	No change/0	No change	Open	Time <=5 seconds
Air purge	Stop/0	Run/50	No change	Open	Time >=8 seconds
Pause	Stop/0	Stop/0	Recirculate	Open	Time >=2 seconds
Reset	Stop/0	Stop/0	Recirculate	Open	Time >=0 seconds

FIG. 17b

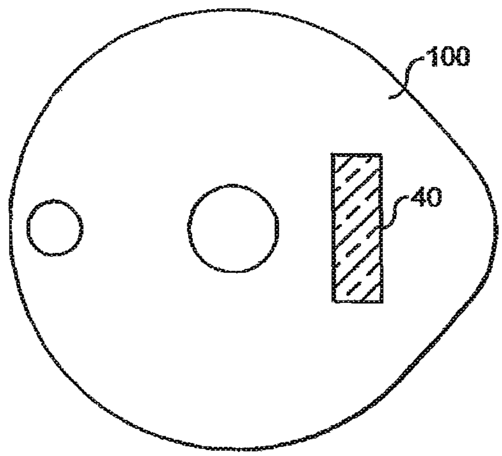
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FIG. 18

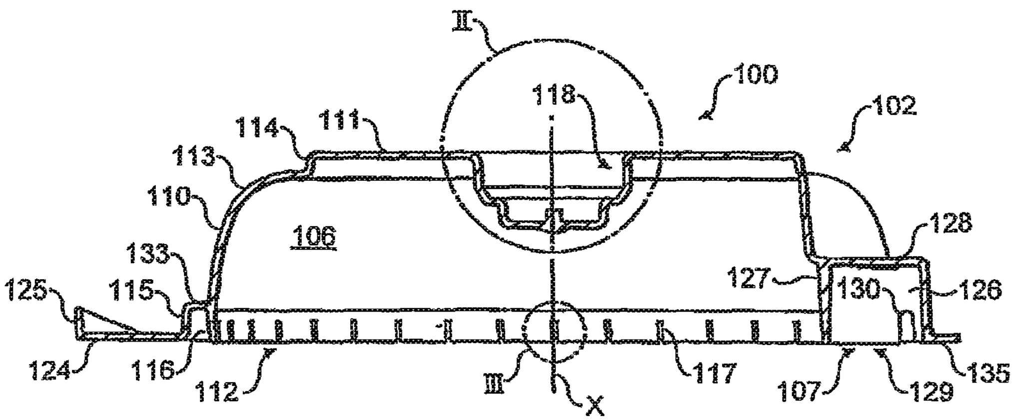
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FIG. 19

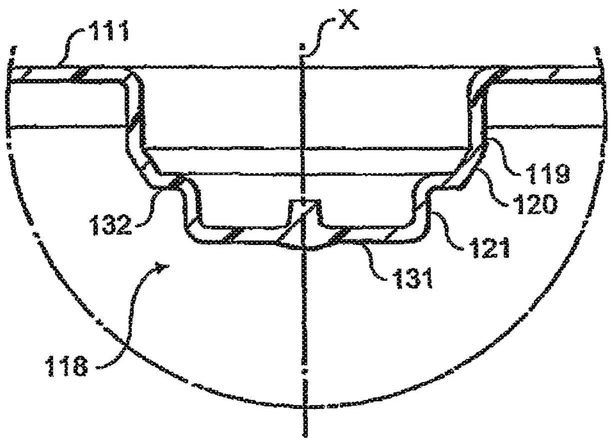


FIG. 20

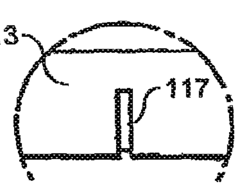
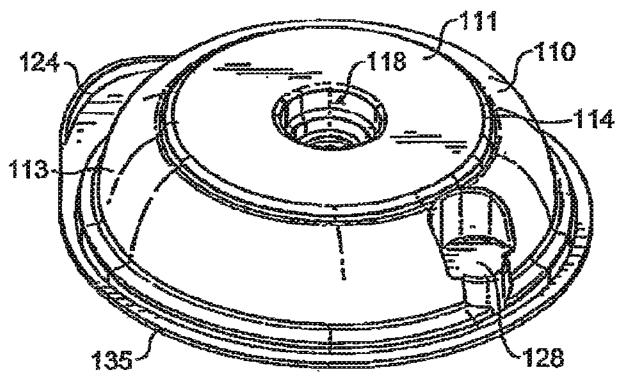


FIG. 21



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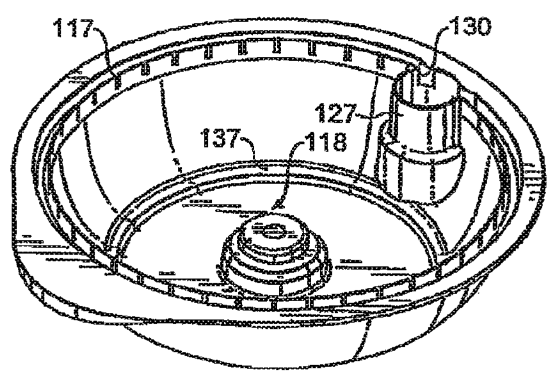

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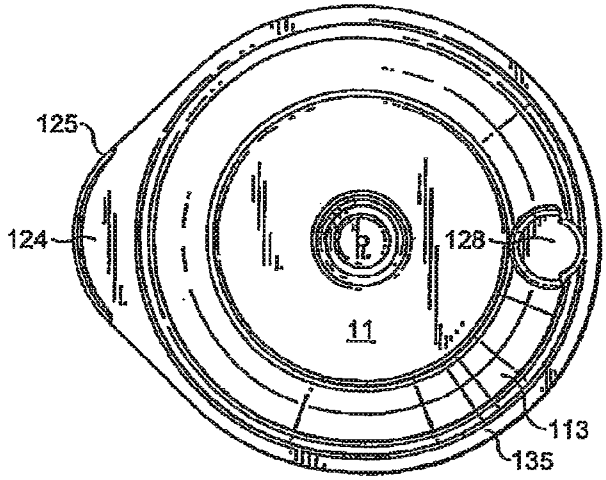

FIG. 24

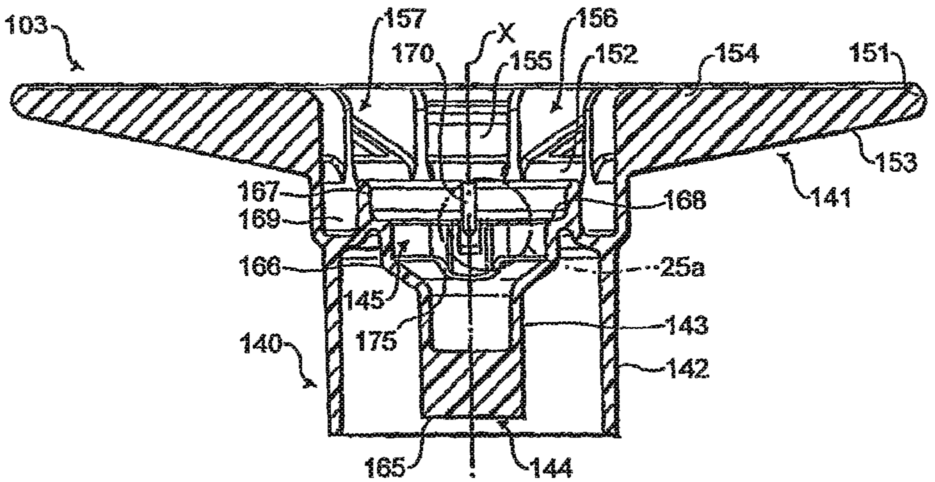

FIG. 25

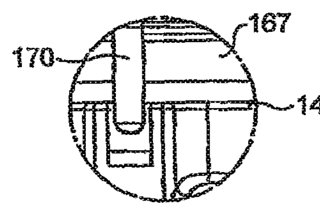

FIG. 25a

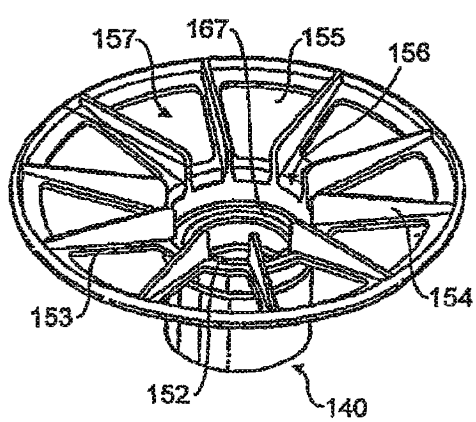

FIG. 26

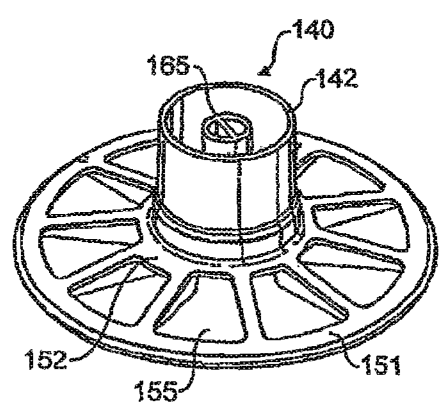

FIG. 27

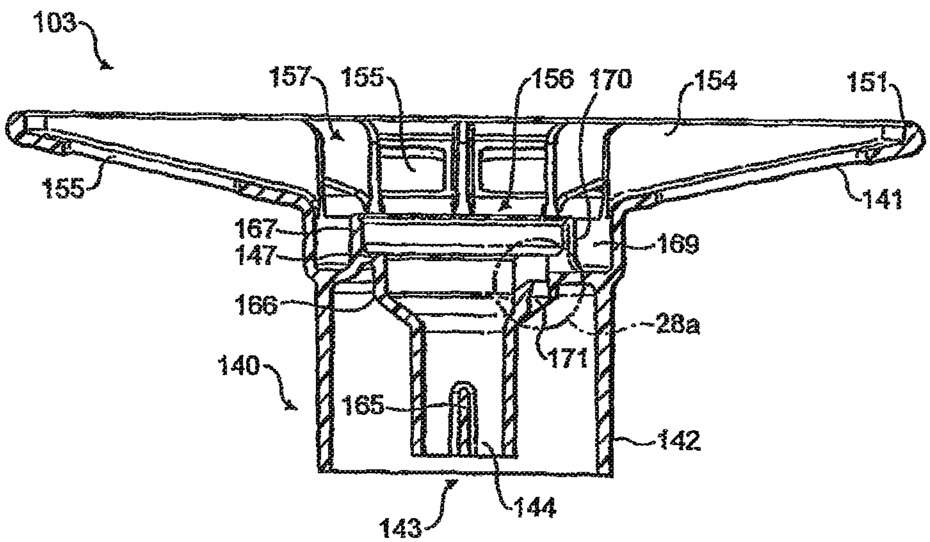

FIG. 28

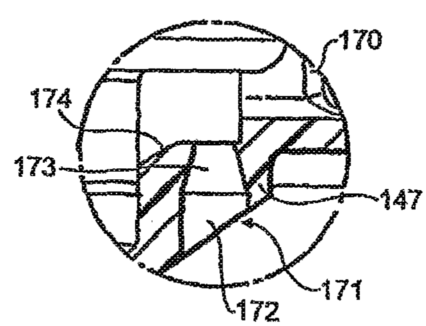

FIG. 28a

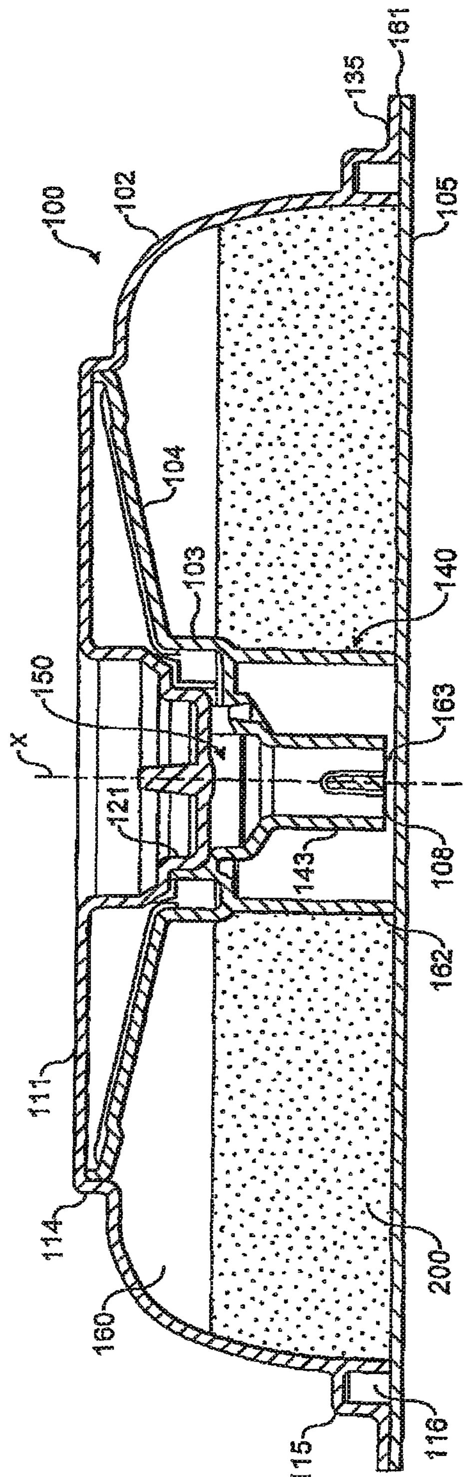
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FIG. 29

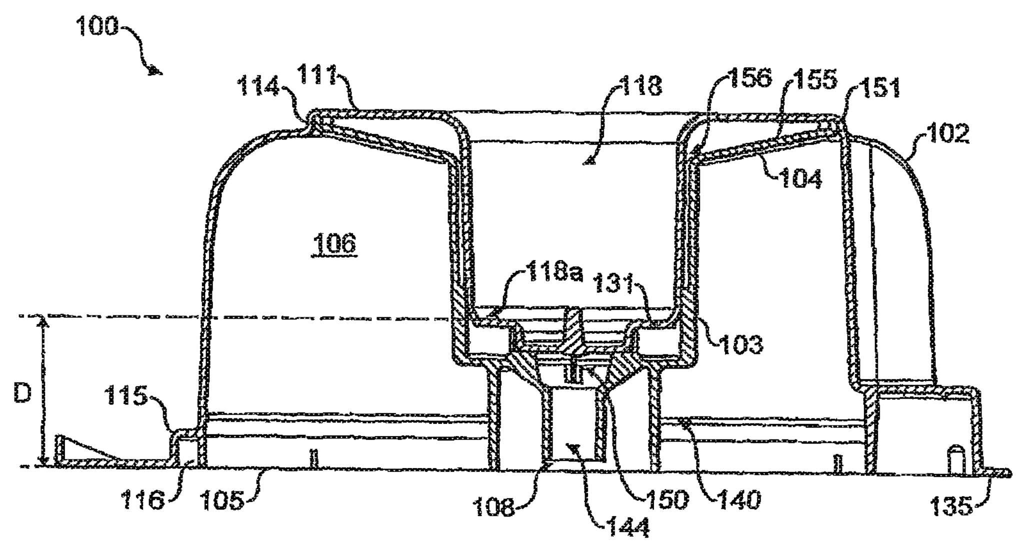
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FIG. 30

BEVERAGE PREPARATION MACHINES

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a divisional of U.S. application Ser. No. 13/318,044, filed Oct. 28, 2011, which is a U.S. national phase application of International Appl. No. PCT/GB2010/000551, filed Mar. 24, 2010, which claims benefit from Great Britain Appl. No. 0907612.6, filed May 1, 2009, and which are hereby incorporated by reference in their entirety.

FIELD

The present invention relates to improvements in beverage preparation machines and in particular to a beverage preparation machine of the type which uses pre-packaged containers of beverage ingredients.

BACKGROUND

Coffee houses have been a part of the "coffee culture" since the 17th century. Throughout the years methods of making coffee have been refined and skilled people trained to produce the best coffee beverages. The first coffee machines were developed in the early 1800s and an automatic espresso machine was invented in the 1930s. The automation of the coffee making process has, in turn, lead to a rapid growth, particularly in the last ten years, in the number of coffee houses/shops with more specialist drinks, such as espresso and cappuccino, being in high demand. These types of beverages have historically been regarded as luxury items because of the need for expensive, complex machines capable of producing the high pressures necessary for making them, which had to be properly operated and maintained by a trained barista to produce good quality. Coffee aficionados agree that an espresso can be spoiled by a badly trained operator despite the use of a good quality machine and good quality coffee. This trend, however, has not only lead to an increased demand from consumers for luxury top quality beverages, but also a desire for a greater variety of speciality beverages, and the ability to make such beverages in the comfort of one's own home.

Although there is no agreed technical definition, it is generally understood that, compared to drip coffee, barista quality espresso has a thicker consistency, due to a higher amount of dissolved solids and fine oil droplets suspended throughout the drink. It has a smooth, yet thick, dark reddish brown crema making up 10 to 30% of the beverage. The crema is a polyphasic emulsion of air and the oils, proteins and sugars extracted from the coffee which is produced at a high pressure, traditionally in the region of 9 to 10 bar. The higher pressures increase the rate of coffee wetting and improve extraction as well as being responsible for the development of the crema.

It is acknowledged, by discerning espresso drinkers, that espresso produced using water which is cooler than the optimum temperature tastes sour and that produced with water which is hotter than this temperature tastes bitter. The optimum temperature is claimed to be between 92 and 96° C. Other factors which affect the quality of the espresso include the roasting and age of the coffee beans, the grind size, the compaction of the grinds prior to brewing, and the brew time. The "best" espresso is achieved by balancing these key elements of the brewing process.

Domestic coffee machines have also developed significantly since the first filter machines were invented in the

1960s and coffee machines are now essential pieces of kitchen equipment in many households. Some such machines dispense individual servings of a beverage directly into a drinking receptacle, and derive the beverage from a bulk supply of beverage ingredients or from individual packages of beverage ingredients such as pods, pads or cartridges. In the following specification such packages will be referenced by the general term cartridges. Machines which use such cartridges eliminate the need for cleaning and can enable the user to make a selection of beverages. An example of one type of such cartridge is described in EP-A-1440903. The beverages are formed from brewing, mixing, dissolving or suspending the beverage ingredients in water. For example, for coffee beverages, heated water is forced through the cartridges to form the extracted solution. The use of cartridges in such machines has become increasingly popular due to their convenience and the quality of the beverage produced.

An example of a machine for preparing beverages using this type of cartridge is described in EP-A-1440644. This type of machine provided, inter alia, an improvement over the prior art known at the time in that it operated at a lower pressure than the previously known machines, which were designed for the commercial or industrial markets rather than the domestic market. Hence it was more suitable for the domestic market in terms of cost, reliability and performance. However, the problem that faces systems that operate at a lower pressure is that they are generally not capable of producing barista quality espressos, which require a significantly higher pressure.

With the change in consumer trends, however, there is a desire for domestic machines which are capable of producing barista quality espresso and a range of other beverages, for which no training is necessary, which are affordable and which require little or no cleaning.

Some machines available on the market claim to produce higher quality beverages but for various reasons, they are comparatively expensive machines. Examples of such machines are the Gaggia L'Amante™, the Gaggia Evolution™, the Nespresso Delonghi Latissimma 660 ™, and the Krups XN2101™.

Most of these machines require specially designed cartridges of increased complexity and a particular specification of materials to cope with the high pressures involved in the brewing process for espresso. These cartridges generally incorporate filters and the process uses the geometry of the cartridge to enable the desired quality of the beverage to be produced under high pressure. This constrains the use of the cartridges in the machine for which it is designed.

SUMMARY

It is, however, desirous to provide an improved beverage preparation machine capable of making a selection of beverages, including a premium quality espresso as well as non-espresso beverages, preferably using pre-packed beverage cartridges. The machine may also be a bulk brewer or other non-cartridge machine.

It is also desirous to provide a machine which is backwardly compatible with existing cartridges, such as those described in EP-A-1440903, which are used in existing low pressure beverage preparation machines.

Accordingly, the present invention provides a method of preparing beverages using a beverage preparation machine for preparing beverages from one or more beverage ingredients, characterised by controlling the volume of gas in at least a part of a delivery system of the machine to produce predetermined characteristics in a prepared beverage.

The volume of gas is preferably actively controlled by increasing the volume to increase the gas:liquid ratio in the beverage produced, decreasing the volume to decrease the gas:liquid ratio or maintaining the volume.

Preferably the volume of gas in the delivery system is controlled by inducting additional gas into the delivery system, venting gas from the delivery system and/or purging the delivery system.

The method preferably further comprises the step of measuring the actual volume of gas resident in the delivery system.

An actual volume of gas resident in the delivery system may be calculated from stored parameters relating to a volume of gas remaining in the delivery system after a last operation of the machine.

Control of the volume of gas is preferably effected on a beverage by beverage basis and is preferably effected automatically according to the type of beverage being produced.

Alternatively the control of the volume of gas is effected manually.

The volume of gas upstream and/or downstream of the beverage ingredients may be controlled.

Preferably the volume of gas is controlled by selectively opening and/or closing valve means in the delivery system prior to and/or during beverage preparation.

The invention also provides a beverage preparation machine for preparing a beverage from one or more beverage ingredients, characterised by the provision of means for controlling the volume of gas in at least a part of a delivery system of the machine to produce predetermined characteristics in a prepared beverage.

The machine preferably comprises means for determining the actual volume of gas resident in the delivery system.

The means for determining the actual volume of gas resident in the delivery system may comprise means for calculating the actual volume from stored parameters relating to a volume of gas remaining in the delivery system after a last operation of the machine.

Preferably the stored parameters comprise a basic volume parameter stored in the control means, said basic volume being the actual volume of gas which resides in the delivery system of an unused machine or a machine after a purging cycle has been run.

The stored parameters may comprise parameters relating to the actual volume of gas remaining in the delivery system after each type of beverage which the machine is programmed to prepare.

The means for determining the actual volume of gas resident in the delivery system preferably comprise means for measuring the actual volume of gas in the delivery system.

Parameters relating to predetermined volumes of gas required to be present in the delivery system for preparing a predetermined range of beverages are preferably stored in the control means, said control means being programmed to calculate the difference between the predetermined volume required for a beverage in preparation and the actual volume present.

The means for controlling the actual volume of gas may comprise valve and/or purge means for venting gas and/or pump means for injecting additional gas into the delivery system.

Preferably the valve means comprise an outlet valve downstream and/or a valve upstream of the beverage ingredients.

Operation of the valve means is preferably controlled relative to the beverage preparation cycle to vary the actual volume of gas present in the delivery system.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings in which:

FIG. **1** is a front perspective view of a prior art beverage preparation machine with the cartridge head in a closed position;

FIG. **2** is a front perspective view of the machine of FIG. **1** with the cartridge head in an open position;

FIG. **3** is a rear elevation of the machine of FIG. **1** with some parts omitted for clarity;

FIG. **4** is a front perspective view of a cartridge head of the machine of FIG. **1** with some parts omitted for clarity;

FIG. **5** is another front perspective view of the cartridge head of FIG. **4**, with some parts omitted for clarity;

FIG. **6** is a cross-sectional view of the cartridge head of FIG. **4** in a closed position accommodating a version of a beverage cartridge;

FIG. **7** is a cross-sectional side elevation of the cartridge head of FIG. **4** in an open position accommodating the beverage cartridge;

FIG. **7***a* is a plan view of a rubber seal for the cartridge head of FIG. **4**;

FIG. **8** is a schematic showing the various component parts of the machine of FIG. **1** incorporating a new variable outlet valve;

FIG. **9** is a section of schematic of an outflow from the cartridge head incorporating the variable outlet valve of FIG. **8**;

FIGS. **10-12** are cross-sectional front elevations of one embodiment of the variable valve in the outflow of FIG. **9** showing it's closed, open and restricted positions respectively;

FIGS. **13***a* and **13***b* are cross-sectional end elevations of an alternative variable outlet valve used in the outflow of FIG. **9** in its open and closed position respectively;

FIGS. **14** and **15** are cross-sectional side elevations of the valve of FIGS. **13***a* and **13***b;*

FIG. **16***a* is a side elevation of a beverage receptacle containing a coffee beverage having a large volume of crema produced using an improved gas management system;

FIG. **16***b* is a chart showing the brew parameters used in producing the beverage illustrated in FIG. **16***a;*

FIG. **17***a* is a side elevation of a beverage receptacle containing a coffee beverage having a small volume of crema produced using the improved gas management system;

FIG. **17***b* is a chart showing the brew parameters used in producing the beverage illustrated in FIG. **17***a;*

FIG. **18** is a plan view of a beverage cartridge suitable for use in the beverage preparation machine of FIG. **1**;

FIG. **19** is cross-sectional side elevation of an outer member of the cartridge of FIG. **18**;

FIG. **20** is a cross-sectional side elevation of a detail of the outer member of FIG. **19** showing an inwardly directed cylindrical extension;

FIG. **21** is a cross-sectional side elevation of a detail of the outer member of FIG. **19** showing a slot;

FIG. **22** is a perspective view from above of the outer member of FIG. **19**;

FIG. **23** is a perspective view from above of the outer member of FIG. **19** in an inverted orientation;

FIG. **24** is a plan view from above of the outer member of FIG. **19**;

FIG. **25** is a cross-sectional drawing of an inner member of the cartridge;

FIG. **25***a* is a cross-sectional drawing of a detail of the inner member of FIG. **25** showing an aperture;

FIG. **26** is a perspective view from above of the inner member of FIG. **25**;

FIG. **27** is a perspective view from above of the inner member of FIG. **25** in an inverted orientation;

FIG. **28** is another cross-sectional drawing of the inner member of FIG. **25**;

FIG. **28***a* is a cross-sectional drawing of another detail of the inner member of FIG. **25** showing an air inlet;

FIG. **29** is a cross-sectional side elevation of the cartridge in an assembled condition; and

FIG. **30** is a cross-sectional side elevation of another version of cartridge.

DETAILED DESCRIPTION

In order to cater for the desired wide selection of good quality beverage types, having different characteristics, the present invention involves one or more significant improvements to known beverage preparation machines. These improvements enable sufficiently high pressures to be generated and maintained for the production of good quality espressos, and the pressure to be varied in a manner which is invisible to the user and requires no manual intervention. Furthermore they enable the crema to be improved in a way not previously possible.

These improvements, which will be described in more detail below, include:—

1. providing a variable geometry valve downstream of the beverage cartridge to enable the beverage preparation machine to operate at a range of pressures; and

2. providing greater control over the end appearance of the dispensed beverage, in particular beverages with crema, by controlling the volume of gas passed through the beverage ingredients.

The aforementioned improvements will be described with reference to a known beverage preparation machine **10** which is illustrated in FIGS. **1** to **7** of the accompanying drawings. It should be noted, however, that the improvements find application in a wide range of beverage preparation machines capable of using a wide range of cartridges which, as noted above, include pods, pads, rigid and semi-rigid cartridges.

The beverage preparation machine **10** of FIGS. **1** to **3** generally comprises a housing **11**, a tank **12**, a water heater **13**, a control processor (not shown), a user interface **16** and a cartridge head **17**. The cartridge head **17** in turn generally comprises a cartridge holder **18** for holding, in use, a beverage cartridge **100** and cartridge recognition means **20**. The cartridge head **17** further comprises inlet and outlet piercers **21**, **22** for forming in the beverage cartridge **100**, in use, an inlet **107** for liquid to enter the cartridge **100** and an outlet **108** for the prepared beverage to exit the beverage cartridge **100**.

Although water is likely to be the most common liquid used in preparing beverages such as coffee, the machine **10** is also capable of handling other liquids, such as milk or milk preparations, for mixing with the beverage ingredients **200**. Any references herein to water should also be taken to include any form of liquid used in preparing beverages.

The housing **11** is preferably made in whole or in part from a suitable plastics material or metal. The housing **11** preferably comprises a clam-shell design having a front half **25** and a rear half **26** which allow access during assembly for fitting of the machine **10** components.

The front half **25** of the housing **11** defines a dispensing station **27** where dispensation of the beverage takes place, which includes a cupstand **23** with a drip tray located beneath. The machine user interface **16** is also located on the front of the housing **11** and comprises a plurality of control switches, for example, a start/stop button **28**, and a number of status indicators **29**-**32**. The status indicators **29**-**32** are preferably light emitting diodes (LED) which, for example, indicate readiness of the machine **10**, whether an error has occurred in the machine **10** operation, and the mode of operation of the machine **10**. The LEDs **29**-**32** may be controlled to illuminate at a constant intensity, to flash intermittently, or both depending on the status of the machine **10**. The LEDs **29**-**32** may have a variety of colours including green, red and yellow. The start/stop button **28** controls commencement of the dispense cycle and is preferably a manually operated push-button, switch or similar.

The tank **12** is located to the rear of the housing **11** and is preferably incorporated in, or connected to, the rear half **26** of the housing **11**. The tank **12** has an inlet for filling the tank **12** with water, or other liquid, which is closed off when the tank **12** is in position in the machine **10**. An outlet is provided towards a lower end of the tank **12** which communicates with the pump **14**. The tank **12** may be made from a transparent or translucent material to allow a consumer to view the quantity of water remaining in the tank **12**. Alternatively, the tank **12** may be made from an opaque material but have provided a viewing window therein. In addition, or in place of the above, the tank **12** may be provided with a low level sensor which prevents operation of the pump **14** and optionally triggers a warning indicator, such as an LED, when the liquid level in the tank descends to a preselected level. The tank **12** preferably has an internal capacity of approximately 1.5 liters.

The pump **14** is operatively connected between the tank **12** and the water heater **13**, as shown schematically in FIG. **8**, and is controlled by the control processor. A suitable pump provides a flow rate of 900 ml/min of water at a pressure of 6 bar. The flow rate of water through the machine **10** can be controlled by the control processor to be a percentage of the maximum flow rate of the pump **14** by cycle chopping the electrical supply to the pump. Preferably the pump can be driven at any of 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90% or 100% of the maximum rated flow rate. The accuracy of the volume of water pumped is preferably + or −5% leading to a + or −5% accuracy in the final volume of the dispensed beverage. A volumetric flow sensor (not shown) is preferably provided in the flow line either upstream or downstream of the pump **14**. Preferably, the volumetric flow sensor is a rotary sensor.

The heater **13** is located in the interior of the housing **11**. One suitable heater **13** has a power rating of 1550 W and is able to heat water received from the water pump **14** from a starting temperature of approximately 20° C. to a nominal operating temperature of around 85° C. in under 1 minute. Preferably the dwell time between the end of one dispense cycle and the heater **13** being able to commence a subsequent dispense cycle is less than 10 seconds. The heater maintains the selected temperature to within + or −2° C. during the dispense cycle. The water for the dispense cycle is delivered to the cartridge head **17** at a predetermined temperature. The heater **13** is able to quickly adjust the delivery temperature to the required temperature, generally between 80° C. and 98° C. and possibly higher from the incoming water temperature. Where desired, the machine can incorporate a steam purge. The preferred means of generating the steam purge is to utilise a water heater **13** in the form of a flash (also known as an instantaneous or flow) heater. Typically such flash heaters comprise a tube through which the water passes wherein the tube is heated by one or more resistive elements. The flash heater can be used not only for heating water for forming beverages but also, at higher power settings, for generating a steam purge by boiling off water remaining with the flash heater tube after the beverage has been formed. An advantage of flash heaters is that there is no significant delay whilst water in a boiler heats up. Flash heaters heat water on demand and switch off immediately after each brewing cycle and are therefore very energy efficient.

Water output from the heater **13** is fed via a suitable delivery system to the cartridge head **17** and cartridge **100** by means of a valve. If the pressure of the water flow is acceptable, the water is passed to the cartridge **100**. If the pressure is below or above predetermined limits then the water is diverted by means of the valve to a waste recovery receptacle.

The delivery system comprises conduits which connect the tank **12**, the water pump **14**, the water heater **13** and the cartridge head **17** (as shown in FIG. **8**) to transport the water from the tank **12** to the cartridge **100**.

The cartridge holder **18** is designed to be capable of handling the opening forces generated by the pressure inside the cartridges **100**, which is around 250 kg for espresso beverages. During operation of the machine **10** the cartridges **100** attempt to expand, but the integrity of the cartridges **100** must be maintained. In addition the user must not be able to open the holder **18** whilst the system is pressurised and suitable locking mechanisms are provided to achieve this.

One suitable design of cartridge head **17**, as described in WO-A-2006/014936, is shown in FIGS. **4** to **7**. The cartridge holder **18** of the cartridge head **17** comprises a fixed lower part **43**, a rotatable upper part **44** and a pivotable cartridge mount **45** positioned between the fixed lower part **43** and the rotatable upper part **44**. The upper part **44**, lower part **43** and cartridge mount **45** are rotated about a common hinge axis **46**. FIGS. **4** to **7** show the holder **18** with some components of the machine **10** omitted for clarity.

The rotatable upper part **44** and pivotable cartridge mount **45** are moved relative to the fixed lower part **43** by means of a clamping mechanism. The clamping mechanism comprises a clamping lever having first and second members or parts **47** and **48**. The first part **47** of the clamping lever comprises a U-shaped arm which is pivotably mounted to the upper part **44** at two first pivot points **48**, one on each side of the holder **18**.

The second part of the clamping lever comprises two over-centre arms **49**, one on each side of the holder **18** which are each pivotably mounted to the upper part **44** at a second pivot point **50** located on the hinge axis **46** coupling the upper part **44** to the fixed lower part **43**. Each over-centre arm **49** is a reciprocal member comprising a cylinder **49***a*, a stem **49***b* and a resilient sleeve **49***c*. The cylinder **49***a* has an internal bore and is rotatably mounted at one end at the hinge axis **46**. A first end of the stem **49***b* is slidingly received in the bore of the cylinder **49***a*. The opposite end of the stem **49***b* is rotatably mounted to the U-shaped arm **47** at a third pivot point **51**. The third pivot points **51** are unconnected to, and freely moveable relative to, the upper part **44** and lower part **43**. The resilient sleeve **49***c* is mounted externally on the stem **49***b* and extends, in use, between abutment surfaces on the cylinder **49***a* and stem **49***b*. The resilient sleeve **49***c* accommodates shortening of the over-centre arm **49** but biases the over-centre arm **49** into an extended configuration. Movement of the third pivot points **51** towards and away from the hinge axis **46** is thus possible by relative movement of the stems **49***b* in the cylinders **49***a*. The resilient sleeves **49***c* are preferably formed from silicone. Whilst the illustrated embodiment uses two over-centre arms **49**, it will be apparent that the closure mechanism may be configured with only one over-centre arm **49**.

The U-shaped arm **47** extends around the front of the holder **18** and comprises two downwardly dependant hook members **52**, one on each side of the holder **18**, each comprising a cam surface facing the hinge axis **46**. The fixed lower part **43** of the holder **18** is provided with two bosses **53**, or detents, located one on each side of the lower part **43** at or near a front edge **54** thereof aligned generally with the hook members **52**.

As shown in FIG. **4**, the U-shaped arm **47** may be formed from a one piece plastics moulding comprising an ergonomic hand grip and the hook members **52** integral to the arm **47**.

The cartridge mount **45** is rotatably mounted between the upper and lower parts **43**, **44** of the holder **18**. The mount **45** is provided with a substantially circular recess **55** which receives in use the beverage cartridge **100** (which is described in greater details below). The recess **55** includes an irregularity **56** for accommodating the handle portion **24** of the beverage cartridge **100** which also acts to prevent rotation of the beverage cartridge **100** in the holder **18**. The cartridge mount **45** is sprung relative to the fixed lower part **43** such that in the open position, as shown in FIG. **7**, the cartridge mount **45** is biased out of contact with the fixed lower part **43** so that the cartridge mount **45** is moved out of contact with the outlet and inlet piercer members **21**, **22**. The cartridge mount **45** is provided with an aperture **57** for receiving there through the inlet and outlet piercers **21**, **22** and a head of the cartridge recognition means **20** when the cartridge mount **45** is moved into the closed position.

The upper part **43** comprises a generally circular body **58** housing a circular viewing window **59** through which a consumer can view the beverage cartridge **100** during a dispense cycle and also visually confirm whether a cartridge **100** is loaded in the machine **10**. The viewing window **59** is cup-shaped having a downwardly directed rim. In addition, the viewing window **59** is provided with a clamping member in the form of an inwardly directed tubular extension **61** as shown in FIG. **7**. The extension **61** is directed towards the lower part **44** and lies within the volume of the cartridge head when in the closed position as shown in FIG. **6**. The viewing window **59** is able to move axially relative to the housing **58** of the upper part **43**. One arrangement of accomplishing the relative movement is to provide a wave spring (not shown), or similar resilient means such as a rubberised ring, positioned between the viewing window **59** and the circular housing **58**. In an alternative arrangement, a series of helical compression springs (not shown) are provided extending between the viewing window **59** and the housing **58**. In both cases the resilient means allows the viewing window **59** to move axially relative to the circular housing **58** by a small degree.

When the holder **18** is in the closed position, a distal end **62** of the tubular extension **61** of viewing window **59** bears against the clamping surface **18***a* of the beverage cartridge **100** biasing it against the lower part **44** as shown in FIG. **6** (in which the arrangement is illustrated containing a cartridge having a greater depth). The pressure exerted by the tubular extension **61** on the outer member **102** ensures a fluid tight seal between the cartridge **100** and the holder **18**. It should be noted that the height of the viewing window **59**, and hence also the cartridge head **17**, is such that cartridges **100** of various depths can be inserted. In FIG. **6** the arrangement is shown with a relative deep cartridge. The same cartridge head **17** can also accommodate shallower cartridges. In this case there will be a gap between the upper surface **11** of the cartridge **100** and the window **59**. However the cartridge **100** is fully sealed at inlet and outlet by the pressure applied by the tubular extension **61**.

The lower part **43** comprises the inlet and outlet piercers **21**, **22** and the head of the cartridge recognition means **20**. The inlet piercer **21** comprises a hollow needle-like tube **63** having a sharpened end **64** for perforating the laminate **108** of the beverage cartridge **100** in use. The inlet piercer **21** is in fluid communication with a water conduit **65**, as shown in FIG. **7**, which passes through the lower part **43** and is connected to an outlet conduit **66** of the water heater **13**. The outlet piercer **22** is similar in type to the outlet piercer described in the EP-A-0389141 and EP-A-0 334572 and comprises an open ended cylinder of circular or D-shaped cross-section having dimensions larger than the beverage discharge spout **109**. An arcuate portion **67** of the upper end of the outlet piercer **22** is serrated to pierce and eventually cut the laminate of the beverage cartridge **100**. The remainder of the upper end is cut back longitudinally of the cylinder at least to the base of the teeth **68** of the serrated portion to fold or pull the cut laminate **108** away from the outlet aperture before the beverage is dispensed there through. The outlet piercer **22** pierces the laminate **105** externally of the discharge spout **143** and when the cartridge mount **45** is in the closed position, rests in the annulus between the discharge spout **143** and the outer wall **42** of the discharge funnel **140**. The outlet piercer **22** folds back the cut laminate **105** into the annulus. Thereby both the outlet piercer **22** and the cut laminate **105** are held out of the way of the discharged beverage.

The outlet piercer **22** is surrounded by a ledge which is raised relative to its surroundings by 0.5 mm.

Advantageously, the outlet piercer **22** is removable from the lower part **43** to enable it to be thoroughly cleaned, for example, in a dishwasher. The removable outlet piercer **22** is received in a recess in the lower part **43** where it is seated. The inlet piercer **21** and/or the outlet piercer **22** may be made of a metal, such as stainless steel, or from a plastics material. Advantageously, the use of plastic cutting elements is enabled by use of a laminate **105** which is able to be punctured and cut by a non-metallic material. Consequently, the piercers **21**, **22** can be made less sharp which lowers the risk of injury to the consumer. In addition, plastic piercing elements are not prone to rust. Preferably, the inlet piercer **21** and the outlet piercer **24** are formed as a single, integral unit which is removable from the lower part **43**.

In use, the upper part **44** of the holder **18** is movable from an open position in which it is orientated vertically or towards the vertical as shown in FIG. **2**, to a closed position in which it is orientated substantially horizontally and in interengagement with the fixed lower part **43** and cartridge mount **45**. The upper part **44** is moved from the open to the closed positions by operation of the clamping lever. To close the upper part **44** a user takes hold of the clamping lever by the U-shaped arm **47** and pulls downwards. Consequently, the upper part **44** rotates which first brings the tubular extension **61** of the viewing window **59** into contact with the clamping surface **118***a* of the beverage cartridge **100**. Continued rotation of the upper part **44** rotates the upper part **44** and cartridge mount **45** down into contact with the lower part **43**. Further rotation of the U-shaped arm **47** causes the U-shaped arm **47** to rotate relative to the upper part **44** and the lower part **43** resulting in the hook members **52** of the upper part **44** engaging the bosses **53** of the lower part **43** with the cam surface riding over the bosses **53**. During this last stage of rotation the cartridge **100** is compressed between the cartridge mount **45** and the viewing window **59**. As a result, the viewing window **59** is moved axially slightly relative to the circular housing **58** of the upper part **44** against the bias of the wave spring or helical springs. This movement allows for a take up of tolerances in the beverage cartridge **100** and beverage preparation machine **10** and ensures that the amount of compressive force applied to the cartridge **100** is kept within an acceptable range. The clamping force of the mechanism as moderated by the action of the wave spring or helical springs ensures a clamping pressure on the cartridge **100**. It has been found that a force of between 150N and 400N is required to counter the pressure in the cartridge **100**. During closure of the cartridge head the laminate **105** of the cartridge **100** is tensioned as it is brought into contact with the ledge surrounding the outlet piercer **22** which causes the laminate **105** to flex out of plane as the distal end of the outer tube **42** of the cylindrical funnel is moved upwardly by 0.5 mm relative to the flange **147**. This movement also ensures that the great majority of the compressive force applied to the cartridge **100** acts through the central region of the cartridge **100** through the load-bearing inner member **103**. These clamping forces help prevent failure of the cartridge **100** during pressurisation and also ensure that the inner member **103** and outer member **102** are fully seated relative to one another and thus that all internal passageways and apertures remain at their intended dimensions even during internal pressurisation.

In the closed position, the separation of the distal end **62** of the tubular extension **61** and the lower part **44** is shown by reference D in FIG. **6**. This distance is fixed by the dimensions of the viewing window **59**, housing **58** and lower part **44**. The distance D is chosen to be the same or marginally smaller than the distance d between the clamping surface **118***a* and laminate **105** under surface of the cartridges **100**. In this way, on closure of the cartridge head **17** the cartridges **100** are subjected to a fixed, known degree of compression. In addition, both the first and second embodiments of cartridge can be clamped with the same degree of compression since distance D is the same for both cartridge types.

An imaginary datum line can be drawn between the first and second pivot points **48**, **50** of the holder **18**. As can be seen in FIG. **7**, in the open position the third pivot points **51** are located on the side of the datum line nearest the fixed lower part **43**. As the upper part **44** reaches the closed position, the third pivot points **51** of the clamping lever pass through the datum line joining the first and second pivot points **48**, **50** to the opposite side of the line, furthest from the fixed lower part **43**. Consequently, the U-shaped arm **47** 'snaps through' from a first stable position to a second stable position. The snap through action is accommodated by shortening of the over-centre arms **49** and consequential compression of the resilient sleeves **49***c*. Once the third pivot points **51** are past the imaginary datum line, the recovery of the resilient sleeves **49***c* acts to continue the motion of the third pivot points **51** away from the imaginary datum line. The clamping lever thus has a bi-stable operation in that the lever is stable in the open or closed positions but unstable at the point when the third pivot points **51** lie on the imaginary datum line joining the first and second pivot points **48**, **50**.

Thus, the snap-through action of the clamping lever provides a positive closure mechanism which leads to a definite closure action wherein in the final stages of the clamping lever's rotation, the snap-through action of the U-shaped arm **47** and second arms forces the hook members **52** firmly into engagement with the bosses **53**. In addition, the resilient sleeves **49***c* provide a resistance to re-opening of the upper part **44** since a minimum force is required to compress the sleeves **49***c* sufficiently to move the third pivot points **51** back into line with the datum line joining the first and second pivot points **48**, **50**. Advantageously, the interengagement of the hook members **52** and the bosses **53** prevents separation of the upper and lower parts other than by rotation of the clamping lever. This is useful in preventing opening of the cartridge head **17** during operation when the cartridge head **17** is subject to internal pressurisation.

The pressure exerted by the upper section **44** ensures a full fluid tight seal between the cartridge **100** and the cartridge holder **18**. The clamping forces help prevent failure of the cartridge **100** during pressurisation and also ensure that all of the internal passageways and apertures within the cartridge **100** remain at their intended dimensions even during internal pressurisation. To improve the seal with the cartridges **100** the applicant has now found that lining the recess **55** of the cartridge mount **45** with a rubber seal **55***a* (see FIG. **7***a*) improves the machine's ability to withstand the significantly higher pressures generated during the brewing cycle.

Control of the brew cycle is effected by the control processor of the beverage preparation machine **10**, which comprises a processing module and a memory. The control processor is operatively connected to, and controls operation of, the heater **13**, pump **14**, user interface **16**, and other components described below.

The operational behaviour of the machine **10** is determined by software embedded in the control processor, for example as described in EP-A-1440644. The memory of the control processor includes one or more variables for one or more operational parameters for the beverage preparation machine **10**. In the prior art machines these are generally the temperature of the liquid passed through the beverage cartridge **100** during the operating stage, the speed of charging the beverage cartridge **100**, the presence or otherwise of a soak step, the total dispensed volume of the beverage, the flow rate of the liquid during the discharge stage, and the period of the purge stage.

One purpose of the cartridge recognition means **20** is, inter alia, to allow the machine **10** to recognise the type of beverage cartridge **100** that has been inserted and to adjust one or more operational parameters accordingly. The variables for the operational parameters are stored in the memory. The cartridge **100** comprises a code **120** provided on or in the cartridge **100** representing the operational parameters required for optimal dispensation of the beverage in that cartridge **100**. An example of the code is described in EP-A-1440644.

The control processor memory further stores information on the type of beverage dispensed so that the operating cycle of the machine **10** may be adjusted for the next cartridge **100**. This is especially advantageous where two or more beverage cartridges **100** are used sequentially to form a beverage. For example a coffee cartridge may be dispensed followed by a milk cartridge to form a cappuccino beverage. Alternatively a chocolate cartridge could be used followed by a milk cartridge to produce a creamy hot chocolate beverage. By using a memory that stores information on the first beverage dispensed, the manner of dispensing the second cartridge, say a milk cartridge, may be altered to achieve an optimum beverage. In the above example the milk dispensed for hot chocolate may, typically, be diluted less than the milk added to the coffee. In addition, the milk dispensed for chocolate may be dispensed at a slower flow rate to lessen the degree of foaming of the beverage. Many combinations of cartridges are possible and operating parameters as will be obvious to the skilled person. In addition, the memory may be used to allow the machine **10** to 'predict' the type of beverage that a user will next want to dispense. For example, if a user predominantly drinks one beverage type then the machine can instruct the water heater to remain at the optimum temperature for that beverage type.

Operation of the known prior art machines **10** comprises insertion of a beverage cartridge **100** into the cartridge head **17**, carrying out a dispense cycle in which the beverage is dispensed and removal of the cartridge **100** from the machine.

To insert the cartridge **100** the cartridge holder **18** is opened as described above to expose the cartridge mount **45**. The cartridge **100** is then placed on the cartridge mount **45** received within the recess **46**. The cartridge holder **18** is then closed by operation of the clamping handle **51** as described above. During closure the inlet and outlet piercers pierce the cartridge **100** to form the cartridge inlet **107** and outlet **108**.

To commence the operating cycle the user operates the start/stop button **28**. The operating cycle comprises the steps of cartridge recognition and the beverage preparation cycle.

Cartridge recognition is performed by the optical cartridge recognition means **20** as described above assuming that the outputs from the cartridge sensor and lock sensor are satisfactory. Once the barcode **40** has been decoded the operational parameters of the machine **10** are adjusted by the control processor. The preparation cycle is then automatically commenced. The preparation cycle has four main stages, although not all of these are used for all beverage types:

1. Pre-wet
2. Pause
3. Brew stage
4. Purge

In the pre-wet stage the cartridge **100** is charged with liquid from the storage tank **12** by means of the pump **14**. The charging with water causes the beverage ingredients **200** in the chamber **160** to be wetted. The charging may take place at a "fast" flow rate of 600 ml/min or a "slow" flow rate of 325 ml/min. The slow charging rate is particularly useful for cartridges **100** containing viscous liquid beverage ingredients where the ingredients require some dilution before they are able to be pumped at a higher volume flow rate. The volume of liquid injected into the cartridge **100** is selected to ensure that liquid or beverage does not drip out of the cartridge outlet **108** during this stage.

The pause stage allows the beverage ingredients **200** to soak in the liquid injected during the pre-wet stage for a predetermined period of time. Both the pre-wetting and soaking stages are known to increase the yield of the extractibles from the beverage ingredients **200** and to improve the end flavour of the beverage. Pre-wetting and soaking are particularly used where the beverage ingredients are roast and ground coffee.

In the brew stage liquid is passed through the cartridge **100** in order to produce the beverage from the beverage ingredients **200**. The temperature of the liquid is determined by the control processor which sends instructions to the heater **13** to heat the liquid passing from the tank **12** to the cartridge head **17**. Liquid enters the cartridge holder **18** via an inlet valve and the inlet piercer and then passes into the inlet chamber **126** of the beverage cartridge **100**. Brewing and/or mixing of the beverage in the beverage cartridge **100** occurs, as described in EP-A-1440644, before the prepared beverage exits the cartridge outlet **104**, enters the outlet valve **37** and is directed into a suitably placed receptacle in the dispensing station **27**.

During the purge cycle the temperature of the water heater **13** is raised sufficiently high to convert the water remaining in the system to steam and blowing the pressurised steam through the beverage preparation machine **10** and the beverage cartridge **100**. This ensures that all beverage is dispensed and that the flow path is cleared ready for dispensing another beverage. The purge cycle may not commence immediately on cessation of the brew/mixing stage to allow for the majority of the fluid to clear the flow path.

Once the operating cycle has been completed, the machine automatically stops and the consumer removes the cartridge **100** by opening the cartridge holder **18** and manually removing and disposing of the cartridge **100**. Alternatively, the machine **10** may be provided with an automatic ejection mechanism for removing the cartridge automatically on opening the cartridge holder **18**.

The first of the significant improvements to the known beverage preparation machines **10** referred to above is the provision of variable geometry valve **60** (see FIGS. **9** to **15**) provided adjacent the cartridge outlet **108** to provide post-cartridge pressure control. This enables the machine **10** to produce a wide variety of beverages, as it allows the cartridges **100** to be selectively brewed at either high or low pressure or a varying pressure during the brew cycle, depending on the type of brew cycle required for the beverage ingredients in the cartridge as identified by the cartridge recognition means **20**, thus providing an automated variable pressure system. The modified machine is capable of producing beverages at a range of pressures, for example from 0 to 9 bar, and more preferably from 0 to 6 bar.

The variable geometry valve **60** is positioned downstream of the cartridge **100**, and preferably positioned in the beverage outlet **37**, which is partially housed in, and extends from, the lower section **43** of the cartridge head **17** (see FIGS. **6** and **7**). The valve **60** has at least an open and a restricted state, and more preferably all of the states identified below:—

1. Open (FIG. **11**)
2. Restricted (FIG. **12**)
3. Closed (FIG. **10**)
4. Cleaning/purging.

Various types of valve may be used for the outlet valve **60**, such as ball valves, pinch valves, sleeve valves, seat valves or disc valves. The embodiment illustrated in FIGS. **10** to **12** is a ball type valve which has a rotating element **69** located in a chamber **70** in the beverage outlet **37**. The rotating element **69** is rotatable between preset positions to provide the required states. The diameter of the bore of the valve **60** in the unrestricted position is preferably at least 5 mm which is required, for example, for cartridges **100** providing low pressure filter beverages.

An alternative suitable valve is a pinch valve illustrated in FIGS. **13** to **15** which comprises a flexible tube **71**, preferably made of silicon rubber or an elastomeric material, and a clamping mechanism **72**. In the unrestricted position (FIGS. **13***a* and **14**) the beverage flows freely through the tube **71**. The clamping mechanism **72** is activated to provide a restricted position (FIGS. **13***b* and **15**) and closed position.

The valve **60** is controlled automatically by the control processor of the machine **10**. Once the type of cartridge **100** inserted into the machine **10** has been identified, by the decoding the barcode **40**, the control processor selects the correct initial setting and, if appropriate, any subsequent operation of the valve **60** for the relevant beverage type.

The machine **10** can operate in a range of modes, with the valve **60** in one or more positions, some examples of which are:—

1. Valve Open Throughout the Brewing Cycle

When the valve **60** is in its open position the operating pressure is below 2 bar allowing a steady state through flow rate of up to 400 ml/min. The beverage is dispensed under similar conditions to those described in EP-A-1440644. This mode is particularly useful as it renders the machine **10** backwardly compatible with existing cartridges for preparing low pressure beverages, such as tea, foamed milk or chocolate.

2. Valve Restricted Throughout the Brewing Cycle

When the valve **60** is in its restricted position it creates a relatively high back pressure within the cartridge **100**, which results in an operating pressure of up to 4, 6 or even 9 bar and provides a steady state through flow rate of 60 to 300 ml/min. This is sufficient to obtain the necessary solids extraction and emulsification of oils in the beverage ingredients **200** for an espresso beverage. The consequential restriction in the beverage outlet **37** provides a shearing and mixing action in the beverage flowing through the valve **60**, giving rise to good air/liquid emulsification and resulting in an improved crema. This mode can advantageously be used for preparing higher pressure beverages, such as espressos and cappuccinos, from cartridges **100** which do not have means for entraining air to effect the mixing action, i.e. so called non-eductor cartridges.

3. Valve Closed then Restricted

If the valve **60** is closed immediately at the start of the brewing cycle (before the pump **14** commences and during the pre-wet cycle), this enables a higher pressure to be developed within the cartridge **100** than when the valve **60** is in it's restricted position.

Further combinations may be appropriate, such as valve closed then open or valve closed then restricted then open according to the desired effect to be achieved.

If required, the valve **60** can be pulsed between various positions during the brewing cycle, or a part thereof. This manner of valve operation during the delivery cycle enables beverages with a crema having a graduated colour and/or bubble size to be produced.

During the purge cycle the valve **60** is controlled by the control processor to divert the steam to a drain area rather than to the dispensing station **27** to preserve the appearance of the beverage and prevent contamination.

The second of the significant improvements to the known beverage preparation machines **10** referred to above is the addition to the brew control system of gas management. Surprisingly the applicant has now discovered that the characteristics of beverages prepared in this type of beverage preparation machine **10** can be modified beyond boundaries hereto seen in prior art machines. The surprising effect is enacted by controlling the volume of gas in the delivery system during the preparation of the beverage to prescribe the amount of high quality crema resulting in a controlled amount of crema on a beverage varying from a delicate layer up to a surprisingly deep layer in the final beverage. The applicant has found a way to successfully use gases within the beverage preparation machine to modify the gas:liquid ratio to produce a surprising volume of good stable crema in prepared beverages never seen before in prior art machines. Maintaining a greater volume of gas resident in the delivery system enables a much larger gas:liquid ratio to be achieved during brewing and dispensing and this produces a correspondingly larger volume of crema. Decreasing the volume of gas enables the ratio to be decreased to reduce the crema volume. The bubble size is also influenced by the gas:liquid ratio, so a lower ratio can be used to provide a tight and creamy crema and a higher ratio used to provide a more loose and bubbly crema. This improvement therefore provides the ability to optimise the crema volume and bubble size for each beverage dispensed. It has been found that by manipulating the gas good quality espressos can be brewed with a crema volume greater than 25% of the beverage volume whilst minimising the occurrence of bubbles having a diameter of more than 172 microns which is not previously seen to be possible in known beverage preparation machines of this type.

The improvement is achieved by adapting the control of the brew cycle to provide means for managing the volume of gas within the delivery system which conveys the water from the tank **12** to the beverage ingredients **200** and to the dispensing outlet. All further references in this specification to the delivery system are intended to include any predetermined section thereof, for example the section extending from the water heater **13** to the cartridge **100** and may also include, if relevant, some gas contained within a headspace of the cartridge **100**.

The "basic volume" of gas which can reside within the delivery system of any given machine **10** is dependant on its construction. The "actual volume" at any given time will vary according to whether the machine **10** has just been used to prepare a beverage, what type of beverage it was used for and whether a steam purge cycle has been run. Thus the improved brew cycle control incorporates means for varying the volume of gas in the delivery system according to the type of beverage to be dispensed (i.e. one requiring a crema with smaller and fewer bubbles or one which requires a greater froth of larger bubbles) taking into account the actual volume of gas already present. The means for varying the volume of gas may be achieved by combinations of:—

1. purging the delivery system after a brewing cycle is complete, and prior to a subsequent high pressure brew, which will increase the gas:liquid ratio;

2. venting gas from the delivery system prior to high pressure brewing, which will decrease the gas:liquid ratio; and

3. inducting gas into the delivery system prior to high pressure brewing, which will increase the gas:liquid ratio.

Valve means are preferably provided to enable the volume of gas within the delivery system to be reduced and an air pump to enable gas (typically air) to be injected into the system. A separate, dedicated air valve may be incorporated in the delivery system, either upstream or downstream of the cartridge **100**. Preferably the variable geometry valve **60** described above may be used as the valve means.

To enable this improved brew cycle control to be effected, additional parameters to those described in connection with the basic machine **10** may be stored in the memory of the control processor. These additional parameters include the basic volume of gas for the specific construction of machine **10** (which will apply to the machine **10** which is unused or after it has been purged) and the volume required during high pressure brewing for optimising the crema for each specific beverage. Preferably the additional parameters also include the actual volume of gas which will remain in the delivery system after each type of brew operation which the machine **10** is capable of. However this is not wholly necessary if the machine **10** is programmed to run a steam purge cycle after every beverage is dispensed, which effectively resets the actual volume to the basic volume, because it flushes the dispensing system downstream of the water heater **13** of any remaining liquid.

The brew cycle will therefore include an additional step, namely a gas adjustment cycle before the pre-wet cycle. The gas adjustment cycle thus includes:—

1. An assessment of the required volume of gas for the type of beverage to be prepared. This will most conveniently be the selection from the processor memory of the required parameter associated with the cartridge code **120**;

2. The determination of the actual volume of gas currently resident in the delivery means according to the last operation of the machine **10**. This will be the basic volume for an unused machine or if a purge cycle has been run. If the machine has just been used to prepare a beverage and no purge cycle run, the processor ideally selects from the memory the parameter for the remaining gas according to the last beverage. Alternatively, means may also be provided to specifically monitor the volume of gas within the delivery system at any point in time;

3. A calculation of the volume of gas to be inducted into or vented from the delivery system to achieve the required volume;

4. The modification of the volume of gas, if required, by the induction of additional gas (typically air) or the venting of excess gas.

In one example the beverage preparation machine **10** has a basic volume of gas of 36 ml in the section of the delivery means extending between the water heater **13** and the beverage ingredients **200**.

There are a number of different modes of operation for step **4** depending on the outcome of step **3**, depending on what type of valve means are used. If the valve means are downstream of the cartridge, i.e. an outlet valve, one way of controlling the volume of air upstream of the beverage ingredients **200** prior to high pressure brewing is by closing the outlet valve at different points in the brew cycle as follows:—

1. The Correct Volume of Gas is Present

If the processor calculates that it requires the full basic volume of gas (36 ml) for the beverage to be dispensed, as determined from the reading of the code **120**, it closes the outlet valve at the start of the brew cycle, before any water flows from the water heater **13**. This means that the compression of gas in the delivery system will commence immediately and the cartridge **100** will be subject to higher pressures during the pre-wet and soak cycles, with the valve only opening to dispense the resultant beverage. As the outlet valve is closed before the pump **14** is started, all of the 36 ml of trapped gas is mixed in to the resulting beverage and a larger volume of slightly coarser crema is obtained (FIG. **16***a*). In the example shown the volume of crema Y in a graduated glass, flat bottomed beaker was 20 ml compared to the volume of liquid X, which was 50 ml.

The chart shown in FIG. **16***b* represents an example of brew cycle parameters used to produce a beverage in this mode with a large volume of crema under test conditions.

In this chart, a stop condition of 0 seconds (e.g. against the remove gas step) indicates that the step is not carried out.

2. Too Much Gas is Present

If, on the other hand, a beverage with a small volume of crema is indicated by the cartridge **100** inserted and there is an excess of gas present in the system, the outlet valve is closed after the pump **14** has operated for a short time until the excess gas in the delivery system has escaped through the open valve at low pressure. With the valve being closed later in the brew cycle, the required volume of gas is vented to atmosphere via the cartridge **100** and valve, so a smaller quantity of trapped gas is left to be compressed and mixed in to the resulting beverage during high pressure brewing and consequently a smaller volume of finer crema is obtained (FIG. **17***a*). In the example shown the volume of crema Y in a graduated glass, flat bottomed beaker was 5 ml compared to the volume of liquid X, which was 50 ml.

The chart shown in FIG. **17***b* represents an example of brew parameters used to produce a beverage in this mode with a small volume of crema under test conditions.

3. Insufficient Gas Present

If step **3** indicates that more gas needs to be inducted, the outlet valve is closed immediately and the air pump operated until the deficit has been made up. Thereafter high pressure brewing commences.

The following graph is a digital image analysis showing a comparison of the crema characteristics produced by the present beverage preparation machine **10** (machine A) utilising the gas management system and two prior art machines (machines B and C) without such gas management system. Comparing the profiles for each machine from the peak (~172 μm diameter) rightwards (increasing bubble size), it can be seen that machine A exhibits a very tight distribution of small bubbles within the crema. Machine C (the Nespresso Latissma™) which is a high pressure machine which has a pressure rating of around 19 bar and operates at a pressure between 9 and 15 bar) produces a broader/coarser distribution with a number of larger diameter bubbles, whilst machine B (the applicant's own Tassimo/Bosch Machine™) similar to that described in EP-A-1440644 which is a low pressure machine operating at pressures below 2 bar) is coarser still, though without the larger bubbles seen for machine C.

The tail to the left of the chart (extremely small bubbles) is characteristic of the limits of the image analysis systems used to produce the graph, though is qualitatively similar.

Some elements of the control of the gas in the beverage machine **10** may also be effected manually by the use of suitable buttons for the user to press, to indicate the type of beverage being produced and the required crema characteristics.

Whilst this improvement has been described with reference to beverage machines **10** which use cartridges **100**, it may also be used in bulk brewers and other non-cartridge machines.

Embodiments of cartridges **100** which are suitable for use in the machine **10** having the improvements described above are shown in FIGS. **18** to **30**.

The cartridge **100** generally comprises an outer member **102**, an inner member **103** and a laminate **105**. The outer member **102**, inner member **103** and laminate **105** are assembled to form the cartridge **100** which has an interior **106** for containing one or more beverage ingredients, an inlet **107**, an outlet **108** and a beverage flow path linking the inlet **107** to the outlet **108** and which passes through the interior **106**. The inlet **107** and outlet **108** are initially sealed by the laminate **105** and are opened in use by piercing or cutting of the laminate **105**. The beverage flow path is defined by spatial inter-relationships between the outer member **102**, inner member **103** and laminate **105** as discussed below. Other components may optionally be included in the cartridge **100**, such as a filter **104**, as will be described further below.

A first version of cartridge **100** which will be described is shown in FIGS. **19** to **29**. The first version of the cartridge **100** is particularly designed for use in dispensing espresso-style products such as roast and ground coffee where it is desirable to produce a crema. However, this version of the cartridge **100** may be used with other products such as chocolate, coffee, tea, sweeteners, cordials, flavourings, alcoholic beverages, flavoured milk, fruit juices, squashes, sauces and desserts.

As can be seen from FIG. **23**, the overall shape of the cartridge **100** is generally circular or disc-shaped with the diameter of the cartridge **100** being significantly greater than its height. A major axis X passes through the centre of the outer member as shown in FIG. **19**. Typically the overall diameter of the outer member **102** is 74.5 mm±6 mm and the overall height is 16 mm±3 mm. Typically the volume of the cartridge **100** when assembled is 30.2 ml±20%.

The outer member **102** generally comprises a bowl-shaped shell **110** having a curved annular wall **113**, a closed top **111** and an open bottom **112**. The diameter of the outer member **102** is smaller at the top **111** compared to the diameter at the bottom **112**, resulting from a flaring of the annular wall **113** as one traverses from the closed top **111** to the open bottom **112**. The annular wall **113** and closed bottom **112** together define a receptacle having an interior **134**.

A hollow inwardly directed cylindrical extension **118** is provided in the closed top **111** centred on the major axis X. As more clearly shown in FIG. **20**, the cylindrical extension **18** comprises a stepped profile having first, second and third portions **119**, **120** and **121**. The first portion **119** is right circular cylindrical. The second portion **120** is frusto-conical in shape and is inwardly tapered. The third portion **121** is another right circular cylinder and is closed off by a lower face **131**. The diameter of the first, second and third portion **119**, **120** and **121** incrementally decreases such that the diameter of the cylindrical extension **118** decreases as one traverses from the top **111** to the closed lower face **131** of the cylindrical extension **118**. A generally horizontal shoulder **132** is formed on the cylindrical extension **118** at the junction between the second and third portions **120** and **121**.

An outwardly extending shoulder **133** is formed in the outer member **102** towards the bottom **112**. The outwardly extending shoulder **133** forms a secondary wall **115** co-axial with the annular wall **113** so as to define an annular track forming a manifold **116** between the secondary wall **115** and the annular wall **113**. The manifold **116** passes around the circumference of the outer member **102**. A series of slots **117** are provided in the annular wall **113** level with the manifold **116** to provide gas and liquid communication between the manifold **116** and the interior **134** of the outer member **102**. As shown in FIG. **21**, the slots **117** comprise vertical slits in the annular wall **113**. Between twenty and forty slots are provided. In the embodiment shown thirty-seven slots **117** are provided generally equi-spaced around the circumference of the manifold **16**. The slots **117** are preferably between 1.4 and 1.8 mm in length. Typically the length of each slot **117** is 1.6 mm representing 10% of the overall height of the outer member **102**. The width of each slot **117** is between 0.25 and 0.35 mm. Typically, the width of each slot **117** is 0.3 mm. The width of the slots **117** is sufficiently narrow to prevent the beverage ingredients passing there through into the manifold **116** either during storage or in use.

An inlet chamber **126** is formed in the outer member **102** at the periphery of the outer member **102**. A cylindrical wall **127** is provided, as most clearly shown in FIG. **23**, which defines the inlet chamber **126** within, and partitions the inlet chamber **126** from, the interior **134** of the outer member **102**. The cylindrical wall **127** has a closed upper face **128** which is formed on a plane perpendicular to the major axis X and an open lower end **129** co-planar with the bottom **12** of the outer member **102**. The inlet chamber **26** communicates with the manifold **116** via two slots **130** as shown in FIG. **19**. Alternatively, between one and four slots may be used to communicate between the manifold **116** and the inlet chamber **126**.

A lower end of the outwardly extending shoulder **133** is provided with an outwardly extending flange **135** which extends perpendicularly to the major axis X. Typically the flange **135** has a width of between 2 and 4 mm. A portion of the flange **135** is enlarged to form a handle **124** by which the outer member **102** may be held. The handle **124** is provided with an upturned rim **125** to improve grip.

The outer member **102** is formed as a single integral piece from high density polyethylene, polypropylene, polystyrene, polyester, or a laminate of two or more of these materials. A suitable polypropylene is the range of polymers available from DSM UK Limited (Redditch, United Kingdom). The outer member may be opaque, transparent or translucent. The manufacturing process may be injection moulding.

The inner member **103** as shown in FIGS. **25** to **28**, comprises an annular frame **141** and a downwardly extending cylindrical funnel **140**. A major axis X passes through the centre of the inner member **103** as shown in FIG. **25**.

As best shown in FIGS. **26** and **27**, the annular frame **141** comprises an outer rim **151** and an inner hub **152** joined by ten equi-spaced radial spokes **153**. The inner hub **152** is integral with and extends from the cylindrical funnel **140**. Filtration apertures **155** are formed in the annular frame **141** between the radial spokes **153**. A filter **104** is disposed on the annular frame **141** so as to cover the filtration apertures **155**. The filter is preferably made from a material with a high wet strength, for example a non-woven fibre material of polyester. Other materials which may be used include a water-impermeable cellulosic material, such as a cellulosic material comprising woven paper fibres. The woven paper fibres may be admixed with fibres of polypropylene, polyvinyl chloride and/or polyethylene. The incorporation of these plastic materials into the cellulosic material renders the cellulosic material heat-sealable. The filter **104** may also be treated or coated with a material which is activated by heat and/or pressure so that it can be sealed to the annular frame **141** in this way.

As shown in the cross-sectional profile of FIG. **25**, the inner hub **152** is located at a lower position than the outer rim **151**, resulting in the annular frame **141** having a sloping lower profile.

The upper surface of each spoke **153** is provided with an upstanding web **154** which divides a void space above the annular frame **141** into a plurality of passages **157**. Each passage **157** is bounded on either side by a web **154** and on a lower face by the filter **104**. The passages **157** extend from the outer rim **151** downwardly towards, and open into, the cylindrical funnel **140** at openings **156** defined by the inner extremities of the webs **154**.

The cylindrical funnel **140** comprises an outer tube **142** surrounding an inner discharge spout **143**. The outer tube **142** forms the exterior of the cylindrical funnel **140**. The discharge spout **143** is joined to the outer tube **142** at an upper end of the discharge spout **143** by means of an annular flange **147**. The discharge spout **143** comprises an inlet **145** at an upper end which communicates with the openings **156** of the passages **157** and an outlet **144** at a lower end through which the prepared beverage is discharged into a cup or other receptacle. The profile of the discharge spout **43** comprises a stepped profile with a distinct dog-leg **166** near an upper end of the tube **143**.

As shown in FIG. **25**, the discharge spout **143** is provided with a partition **165** which extends part way up the discharge spout **143** from the outlet **144**. The partition **165** helps to prevent the beverage spraying and/or splashing as it exits the discharge spout **143**.

A rim **167** is provided upstanding from the annular flange **147** joining the outer tube **142** to the discharge spout **143**. The rim **167** surrounds the inlet **145** to the discharge spout **143** and defines an annular channel **169** between the rim **167** and the upper portion of the outer tube **142**. The rim **167** is provided with an inwardly directed shoulder **168**. At one point around the circumference of the rim **167** an aperture **170** is provided in the form of a slot which extends from an upper edge of rim **167** to a point marginally below the level of the shoulder **168** as most clearly shown in FIGS. **25** and **25***a*. The slot has a width of 0.64 mm.

An air inlet **171** is provided in annular flange **147** circumferentially aligned with the aperture **170** as shown in FIGS. **28** and **28***a*. The air inlet **171** comprises an aperture passing through the flange **147** so as to provide communication between a point above the flange **147** and the void space below the flange **147** between the outer tube **142** and discharge spout **143**. Preferably, and as shown, the air inlet **171** comprises an upper frusto-conical portion **173** and a lower cylindrical portion **172**. The air inlet **171** is typically formed by a mould tool such as a pin. The tapered profile of the air inlet **171** allows the mould tool to be more easily removed from the moulded component. The wall of the outer tube **142** in the vicinity of the air inlet **171** is shaped to form a chute leading from the air inlet **171** to the inlet **145** of the discharge spout **143**. As shown in FIG. **28***a*, a canted shoulder **174** is formed between the air inlet **171** and the chute to ensure that the jet of beverage issuing from the slot **170** does not immediately foul on the upper surface of the flange **147** in the immediate vicinity of the air inlet **171**.

The inner member **103** may be formed as a single integral piece from polypropylene or a similar material as described above and by injection moulding in the same manner as the outer member **102**.

Alternatively, the inner member **103** and/or the outer member **102** may be made from a biodegradable polymer. Examples of suitable materials include degradable polyethylene (for example, SPITEK supplied by Symphony Environmental, Borehamwood, United Kingdom), biodegradable polyester amide (for example, BAK 1095 supplied by Symphony Environmental), poly lactic acids (PLA supplied by Cargil, Minn., USA), starch-based polymers, cellulose derivatives and polypeptides.

The laminate **105** is formed from two layers, a first layer of aluminium and a second layer of cast polypropylene. The aluminium layer is between 0.02 and 0.07 mm in thickness. The cast polypropylene layer is between 0.025 and 0.065 mm in thickness. In one embodiment the aluminium layer is 0.06 mm and the polypropylene layer is 0.025 mm thick. This laminate **105** is particularly advantageous as it has a high resistance to curling during assembly. As a result the laminate **105** may be pre-cut to the correct size and shape and subsequently transferred to the assembly station on the production line without undergoing distortion. Consequently, the laminate **108** is particularly well suited to welding. Other laminate materials may be used including PET/Aluminium/PP, PE/EVOH/PP, PET/metallised/PP and Aluminium/PP laminates. Roll laminate stock may be used instead of die cut stock.

The cartridge **100** may be closed by a rigid or semi-rigid lid instead of a flexible laminate **105**.

Assembly of the cartridge **100** involves the following steps:

a) the inner member **103** is inserted into the outer member **102**;

b) the filter **104** is cut to shape and placed onto the inner member **103** so to be received over the cylindrical funnel **140** and come to rest against the annular frame **141**;

c) the inner member **103**, outer member **102** and filter **104** are joined by ultrasonic welding;

d) the cartridge **100** is filled with one or more beverage ingredients;

e) the laminate **105** is affixed to the outer member **102**.

These steps will be discussed in greater detail below.

The outer member **103** is orientated with the open bottom **112** directed upwards. The inner member **103** is then inserted into the outer member **102** with the outer rim **151** being received as a loose fit in an axial extension **114** at top **111** of the cartridge **100**. The cylindrical extension **118** of the outer member **102** is at the same time received in the upper portion of the cylindrical funnel **140** of the inner member **103**.

The third portion **121** of the cylindrical extension **118** is seated inside the support rim **167**. The shoulder **132** of the cylindrical extension **118** between the second portion **120** and third portion **121** bears against the upper edge of the support rim **167** of the inner member **103**. An interface zone is thus formed between the inner member **103** and the outer member **102** comprising a face seal between the cylindrical extension **118** and the support rim **167** which extends around nearly the whole circumference of the cartridge **100**. The seal between the cylindrical extension **118** and the support rim **167** is not fluid-tight though since the slot **170** in the support rim **167** extends through the support rim **167** and downwardly to a point marginally below the shoulder **168**. Consequently the interface fit between the cylindrical extension **118** and the support rim **167** transforms the slot **170** into an aperture providing gas and liquid communication between the annular channel **169** and the discharge spout **143**. The aperture is typically 0.64 mm wide by 0.69 mm long.

The filter **104** is then placed over the inner member **103** such that the filter material contacts the annular rim **151**. An ultrasonic welding process is then used to join the filter **104** to the inner member **103** and at the same time, and in the same process step, the inner member **103** to the outer member **102**. The inner member **103** and filter **104** are welded around the outer rim **151**. The inner member **103** and outer member **102** are joined by means of weld lines around the outer rim **151** and also the upper edges of the webs **154**.

As shown most clearly in FIG. **29**, the outer member **102** and inner member **103** when joined together define a void space in the interior **106** below the annular flange **141** and exterior the cylindrical funnel **140** which forms a filtration chamber. The filtration chamber **160** and passages **157** above the annular frame **141** are separated by the filter paper **104**.

The filtration chamber **160** contains the one or more beverage ingredients **200**. The one or more beverage ingredients **200** are packed into the filtration chamber **160**. For an espresso-style beverage the ingredient is typically roast and ground coffee. The density of packing of the beverage ingredients in the filtration chamber **130** can be varied as desired. Typically, for a filtered coffee product the filtration chamber contains between 5.0 and 10.2 grams of roast and ground coffee in a filtration bed of thickness of typically 5 to 14 mm. Optionally, the interior **106** may contain one or more bodies, such as spheres, which are freely movable within the interior **106** to aid mixing by inducing turbulence and breaking down deposits of beverage ingredients during discharge of the beverage.

The laminate **105** is then affixed to the outer member **102** by forming a weld **161** around the periphery of the laminate **105** to join the laminate **105** to the lower surface of the outwardly extending flange **135**. The weld **161** is extended to seal the laminate **105** against the lower edge of the cylindrical wall **127** of the inlet chamber **126**. Further, a weld **162** is formed between the laminate **105** and the lower edge of the outer tube **142** of the cylindrical funnel **140**. The laminate **105** forms the lower wall of the filtration chamber **160** and also seals the inlet chamber **126** and cylindrical funnel **140**. However, a small gap **163** exists prior to dispensation between the laminate **105** and the lower edge of the discharge spout **43**. A variety of welding methods may be used, such as heat and ultrasonic welding, depending on the material characteristics of the laminate **105**.

Advantageously, the inner member **103** spans between the outer member **102** and the laminate **105**. The inner member **103** is formed from a material of relative rigidity, such as polypropylene. As such, the inner member **103** forms a load-bearing member that acts to keep the laminate **105** and outer member **102** spaced apart when the cartridge **100** is compressed. It is preferred that the cartridge **100** is subjected to a compressive load of between 130 and 280N in use. The compressive force acts to prevent the cartridge failing under internal pressurisation and also serves to squeeze the inner member **103** and outer member **102** together. This ensures that the internal dimensions of passageways and apertures in the cartridge **100** are fixed and unable to change during pressurisation of the cartridge **100**.

In use the water, under pressure, enters the cartridge **100** through the inlet **107** into the inlet chamber **126**. From there the water is directed to flow through the slots **117** and round the manifold **116** and into the filtration chamber **160** of the cartridge **1** through the plurality of slots **117**. The water is forced radially inwardly through the filtration chamber **160** and mixes with the beverage ingredients **200** contained therein. The water is at the same time forced upwardly through the beverage ingredients **200**. The beverage formed by passage of the water through the beverage ingredients **200** passes through the filter **104** and filtration apertures **155** into the passages **157** lying above the annular frame **141**.

Beverage in the radial passages **157** flows downwardly along the passages **157** formed between the webs **154** and through the openings **156** and into the annular channel **169** of the cylindrical funnel **140**. From the annular channel **169** the beverage is forced under pressure through the aperture **128** by the back pressure of beverage collecting in the filtration chamber **160** and passages **157**. The beverage is thus forced through aperture as a jet and into an expansion chamber formed by the upper end of the discharge spout **143**. As shown in FIG. **29**, the jet of beverage passes directly over the air inlet **171**. Passage of the beverage through the restriction of the aperture causes the pressure of the beverage to be reduced. As the beverage enters the discharge spout **143** the pressure of the beverage is still relatively low. As a result air is entrained into the beverage stream in the form of a multitude of small air bubbles as the air is drawn up through the air inlet **171**. The jet of beverage issuing from the aperture is funneled downwards to the outlet **144** where the beverage is discharged into a receptacle such as a cup where the air bubbles form the desired crema. Thus, the aperture and the air inlet **171** together form an eductor which acts to entrain air into the beverage. Flow of beverage into the eductor should be kept as smooth as possible to reduce pressure losses. It should be noted that, in the high pressure state, the air eduction mechanism is de-activated.

The sealing of the filter **104** onto the spokes **153** and the welding of the rim **151** with the outer member **102** ensures that there are no short-circuits and all the beverage has to pass through the filter **104**.

FIG. **30** shows a second embodiment of beverage cartridge **100** which can be used in the beverage preparation machine **10** of the present invention. Like components between the first and second embodiments have been referenced with like numerals. Many of the components and functions of the second embodiment of cartridge **100** are the same as for the first embodiment. However, it can be seen from FIG. **30** that the cartridge **100** has a greater overall height compared to the cartridge **100** shown in FIG. **29**. The outer member **102** is taller and thereby defines a larger void space in which a larger quantity of beverage ingredients **200** can be stored. The second embodiment of cartridge **100** is therefore suitable for dispensing larger volumes of beverage. The diameter of the outer member **102** and cartridge **100** are the same as in the first embodiment. Typically the storage volume of the cartridge **100** when assembled is 50 to 58 ml±20%. As with the first embodiment, the upper surface of the outer member **102** is provided with a recess having a clamping surface **118** located at a bottom thereof. According to the present invention, the separation D between surface **118***a* and the underside of the laminate **105** is the same as for the first embodiment. As a result, the elongated recess extends approximately 60% of the distance towards the laminate **105**. This advantageously allows for a simplified clamping arrangement to be used as described below.

Also, the second embodiment of cartridge **100** lacks an eductor air inlet **171**.

The first and second embodiments of cartridge **1** described above are given as examples of an "eductor" type of cartridge and a "non-eductor" type cartridge which may be used with the improved beverage preparation machine described above.

The invention claimed is:

1. A beverage preparation machine for preparing a beverage from one or more beverage ingredients, comprising valve means, a pump for supplying liquid to the beverage ingredients through a delivery system, and means for controlling the opening and closing of the valve means relative to the operation of the pump during a brew cycle to thereby control the volume of air resident in at least a part of a delivery system of the machine to produce predetermined characteristics in a prepared beverage.

2. A beverage preparation machine as claimed in claim **1** further comprising means for determining the actual volume of air resident in the delivery system.

3. A beverage preparation machine as claimed in claim **2** in which the means for determining the actual volume of air resident in the delivery system comprise means for calculating the actual volume from stored parameters relating to a volume of air remaining in the delivery system after a last operation of the machine.

4. A beverage preparation machine as claimed in claim **3** in which the stored parameters comprise a basic volume parameter stored in the control means, said basic volume being the actual volume of air which resides in the delivery system of an unused machine or a machine after a purging cycle has been run.

5. A beverage preparation machine as claimed in claim **3** in which the stored parameters comprise parameters relating to the actual volume of air remaining in the delivery system after each type of beverage which the machine is programmed to prepare.

6. A beverage preparation machine as claimed in claim **2** in which the means for determining the actual volume of air resident in the delivery system comprise means for measuring the actual volume if air.

7. A beverage preparation machine as claimed in claim **2** in which parameters relating to predetermined volumes of air required to be present in the delivery system for preparing a predetermined range of beverages are stored in the control means, said control means being programmed to calculate the difference between the predetermined volume required for a beverage in preparation and the actual volume present.

8. A beverage preparation machine as claimed in claim **3** further comprising valve and/or purge means for venting air and/or pump means for injecting additional air into the delivery system to control the volume of air resident in the delivery system.

9. A beverage preparation machine as claimed in claim **8** in which the valve means comprise an outlet valve downstream of the beverage ingredients.

10. A beverage preparation machine as claimed in claim **8** or in which the valve means comprise a valve upstream of the beverage ingredients.

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